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Prepared by

Timber,
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Forestry
Management

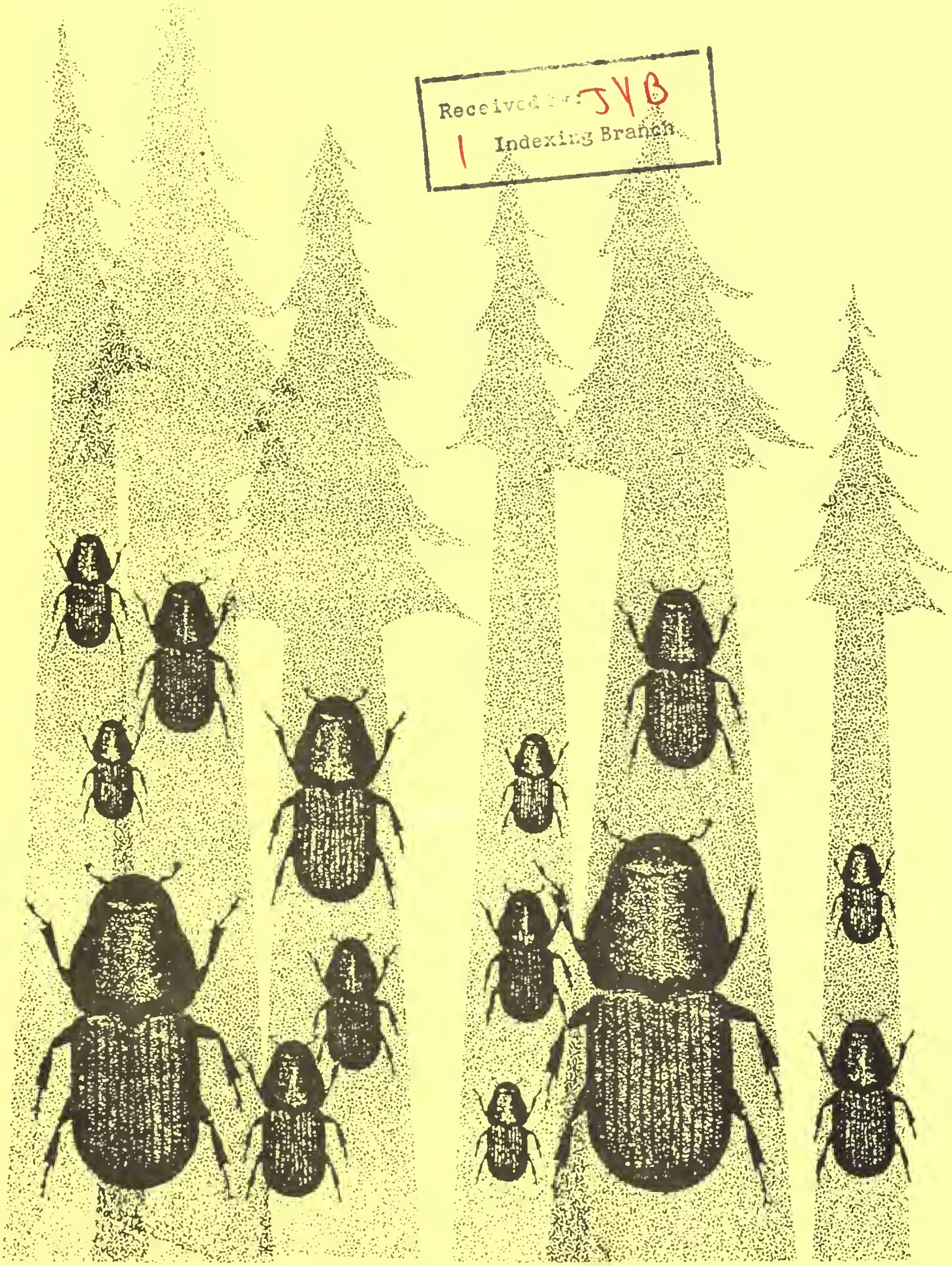
Forest Service
Denver, Colorado



# ANNOTATED BIBLIOGRAPHY

## Mountain Pine Beetle





# ANNOTATED BIBLIOGRAPHY

# MOUNTAIN PINE BEETLE, *DENDROCTONUS PONDEROSAE*, HOPKINS (COLEOPTERA: SCOLYTIDAE)

Gene Lessard

Meg Hansen

Mary Lu Eilers

Revised

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Timber, Forest Pest, and Cooperative Forestry Management
USDA Forest Service
Rocky Mountain Region
11177 W. 8th Avenue
P. O. Box 25127
Lakewood, CO 80225

Agricultural Enterprises, Inc. 1982. Impact assessment of mountain pine beetle and western spruce budworm.

Allen, G. L. 1981. An economic analysis of the Front Range Vegetative Management Project. Univ. of Colo. Business Res. Div., Boulder, CO.

Amman, G. D. 1969. Mountain pine beetle emergence in relation to depth of lodgepole pine bark. USDA For. Serv. Res. Note INT-96, 8 pp.

ABSTRACT

Phloem thickness is one of the important factors affecting mountain pine beetle (*Dendroctonus ponderosae* Hopkins) survival in lodgepole pine (*Pinus contorta* Dougl.). Emergence holes made by adults which completed larval development within the trees were counted on two 6- by 6-inch areas of bark on each tree killed by the mountain pine beetle on twenty 1/10-acre plots. Various tree, stand, and site factors were also measured. Emergence holes ranged from none in bark 0.06 inch thick to an average of 120 per square foot where the bark was 0.18 inch thick. Emergence holes were most closely correlated with bark depth, and varied with stand density and plot elevation. The greatest proportion of thick-barked trees was in the large diameter classes.

Amman, G. D. 1970. Prey consumption and variations in larval biology of *Enoclerus sphegeus* (Coleoptera:Cleridae). Can. Entomol. 102:1374-9.

ABSTRACT

Larvae of *Enoclerus sphegeus* Fabricius (Coleoptera: Cleridae) were separated into three groups for study. Throughout their development, the larvae in each group were fed mountain pine beetle larvae, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), of a specific size (small, medium, or large). Clerid larvae fed small *D. ponderosae* larvae generally completed three stadia, while the other two groups, which were fed medium-sized and large prey, respectively, usually passed through two larval stadia. The number of stadia a larva would have was determined by the amount of food consumed during the first stadium. The feeding period of larvae given small prey was considerably longer than that of those fed medium-sized or large beetle larvae, but the prepupal period was much shorter. The head capsules of second-instar larvae that passed through two stadia were distinctly wider than those of second-instar larvae that completed three stadia.

Amman, G. D. 1972. Some factors affecting oviposition behavior of the mountain pine beetle. Env. Entomol. 1:691-5.

ABSTRACT

Four factors that affect oviposition behavior of *Dendroctonus ponderosae* Hopkins in lodgepole pine, *Pinus contorta* Douglas, were investigated. These were distance between egg galleries, size of the female, phloem thickness, and temperature.

The average number of eggs oviposited per inch of gallery increased with increases in each of the 4 factors. The average number of eggs oviposited per day also increased with increases in each factor except that the effect of distance between galleries was not investigated. The rate of gallery construction increased only with an increase in temperature; it was unaffected by size of female and phloem thickness. Again the effect of distance between galleries was not investigated.

Amman, G. D. 1972. Mountain pine beetle brood production in relation to thickness of lodgepole pine phloem. J. Econ. Entomol. 65:138-40.

ABSTRACT

The effects of phloem thickness of lodgepole pine, *Pinus contorta* Douglas, and number of inches of egg gallery of *Dendroctonus ponderosae* Hopkins on brood production of the beetle were investigated in laboratory studies. Brood production ranged from an average of 16 beetles for phloem 0.09 inches thick to 91 beetles for phloem 0.23 inches thick. Brood production ranged from about 3 beetles for 10 inches of egg gallery to 130 beetles for 174 inches of egg gallery. When food supply limited production, numbers of emerging brood adults increased linearly with phloem thickness. When food supply did not limit production, numbers of emerging brood adults increased exponentially with an increase in inches of egg gallery.

Amman, G. D. 1972. Prey consumption and development of *Thanasimus undulatus*, a predator of the mountain pine beetle. Env. Entomol. 1:528-30.

Amman, G. D. 1973. Population changes of the mountain pine beetle in relation to elevation. Env. Entomol. 2:541-7.

ABSTRACT

*Dendroctonus ponderosae* Hopkins was studied in lodgepole pine, *Pinus contorta* Douglas, at 4 elevations between 1923 and 2750 m in northwestern Wyoming. The beetle had a 1-year life cycle at 1923 and 2130 m. At 2450 m, part of the population completed a generation in one year, but the remainder required two years. Two years usually were required to complete a generation at 2573-2750 m. Life tables showed high mortality rates and declining populations at the 3 highest elevations, in contrast to high survival rates and increasing populations at the lowest elevation. Cool temperatures at high elevations delayed development, so the beetle overwintered in stages that were particularly vulnerable to winter temperatures. The conclusion is that mountain pine beetle populations are regulated by weather at high elevations.

Amman, G. D. 1975. Insects affecting lodgepole pine productivity. In D. M. Baumgartner (ed.). Management of lodgepole pine ecosystems. Wash. St. Univ, Coop. Ext. Serv., Pullman, Vol. 1, pp 310-41.

ABSTRACT

A variety of insects infest lodgepole pine and are capable of limiting productivity during each stage of tree development. Of these, insects of seeds and cones do not appear to be a major factor affecting lodgepole pine management. Insects, such as the lodgepole terminal weevil, that infest and kill terminal shoots cause deformed and multi-stemmed trees of lower merchantable value. Defoliating insects, such as the pandora moth and the needle miner, may kill some trees, but they primarily slow tree growth, which results in lengthened rotation periods. Bark beetles, particularly the mountain pine beetle, are the most serious threat to lodgepole pine management. The beetle periodically kills most of the large diameter trees in a stand. Development of large beetle populations depends upon large trees that have thick phloem, which in turn depends upon good tree vigor. Consequently, stands of large numbers of fast-growing trees will be the first to reach conditions conducive to buildup of beetle populations. Management methods currently offer the best opportunity for regulating beetle populations.

Amman, G. D. 1975. Abandoned mountain pine beetle galleries in lodgepole pine. USDA For. Serv. Res. Note INT-197. 6 pp.

ABSTRACT

During the fall of 1974, 129 galleries of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in 32 recently attacked

lodgepole pines (*Pinus contorta* var. *latifolia* Engelmann) were examined to determine incidence of "pitching out." With one possible exception, galleries containing no females (33 percent) had been abandoned; females had not been pitched out. Small trees generally had a higher proportion of abandoned galleries, and these were usually longer than those in large trees. Low occurrence of males, which probably resulted in low incidence of fertilization in the attacking population on individual trees, is believed to be the factor responsible for gallery abandonment. Fertilized females constructed galleries and oviposited regardless of attack density.

Amman, G. D. 1976. Integrated control of the mountain pine beetle in lodgepole pine forests. Proc. XVI IUFRO World Cong., Div. II, Norway 1976 pp. 439-46.

ABSTRACT

Regulation of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) populations in lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) forests is based on insect-host interactions, and land-use objectives. The mountain pine beetle periodically kills most of the trees of large diameter in a stand. The beetle selects the largest trees where phloem, the food of the larvae, is usually thick and beetle survival is high. Periodicity of infestations is related to rapidity with which a stand of trees grows into diameter-phloem distributions conducive to population buildup.

Forest management practices consisting of clear or partial cuttings are recommended in commercial forests. Particularly susceptible stands can be converted to other tree species, or harvest rotations can be shortened so that trees of small diameter that meet certain product requirements can be cut before the trees reach sizes and phloem thickness susceptible to beetle attack. Regulation of the beetle is not recommended in recreational and noncommercial forests. In these forests, lodgepole pine will be succeeded by spruce and firs. These species will fulfill requirements, of recreation, watershed, and other values as well as lodgepole pine. Chemical insecticides can be used to protect trees of high value from beetle infestation in campgrounds and around home sites.

Amman, G. D. 1977. The role of the mountain pine beetle in lodgepole pine ecosystems: impact on succession. In W. J. Mattson (ed.). The role of arthropods in forest ecosystems. Springer-Verlag, New York. (Proc. 15th Internat. Cong. Entomol.), pp 3-18.

Amman, G. D. 1978. Biology, ecology, and causes of outbreaks of the mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark, D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 39-53.

ABSTRACT

The mountain pine beetle *(Dendroctonus ponderosae* Hopkins) typically produces one generation per year. The year begins with adults infesting trees and introducing blue-stain fungi into them in July and early August. Eggs are laid singly in niches on alternative sides of the vertical egg galleries. Larvae hatch and feed in the phloem, usually at right angles to the egg gallery. Larvae overwinter, then complete development in the spring. Pupation occurs in chambers made in the bark and outer sapwood. During endemic periods, beetles infest weakened and injured trees and those infested by other species of bark beetles. Epidemics appear to start when enough such trees are in proximity and emerging brood adults converge and infest a common tree or group of trees of medium to large diameter and medium to thick phloem. The beetle shows a strong preference for such trees, and its survival usually is best in them. Tree stress is not necessary for the start of epidemics. Stand characteristics associated with epidemics are 1) trees more than 80 years old, 2) average tree diameter more than 20 cm (8 inches), 3) a substantial number of trees in the stand with diameter at breast height of 30 cm (12 inches) or more and phloem 0.25 cm (0.10 inch) thick or more, and 4) stand site at an elevation where temperatures are optimum for brood development.

Amman, G. D. 1980. Mountain pine beetle dynamics in lodgepole pine forests and strategies for reducing tree losses. In Kobayashi, Fujio and Kazumasa Natagiri (eds.). Proceedings, After-Congress Meeting, International Congress of Entomology. Forestry and Forest Products Res. Inst., Tsukuba, Japan.

ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), periodically kills most of the trees of large diameter in a lodgepole pine stand, *Pinus contorta* var. *latifolia* Engelmann. Tree and stand factors conductive to infestations are large diameter trees having thick phloem and elevation of suitable climate for beetle development.

Forest management practices consisting of clear or partial cuttings are recommended for reducing losses in commercial forests. Particularly susceptible stands can be converted to other tree species, or harvest rotations can be shortened so that trees of small diameter that meet certain product requirements can be cut before the trees

reach sizes and phloem thickness susceptible to beetle attack. Control strategies directed against the beetle are not recommended in recreational and noncommercial forests at this time. In these forests, lodgepole pine will be succeeded by spruce and firs. These species will fulfill requirements of recreation, watershed and other values as well as lodgepole pine. Chemical sprays applied to high value trees prior to beetle flight will protect these trees from attack.

Amman, G. D. 1980. Incidence of mountain pine beetle abandoned galleries in lodgepole pine. USDA For. Serv. Res. Note INT-284, 6 pp.

ABSTRACT

Individual lodgepole pines have lower densities of attack by mountain pine beetles and a higher percentage of abandoned egg galleries in stands where beetle populations are low rather than high. Most trees contain some galleries having live beetles, as well as abandoned galleries. Females from galleries likely to be abandoned have been mated, discounting the unfertilized female as a reason for gallery abandonment. The amount and quality of blue-stain fungi carried by the beetle may influence success of gallery construction.

Amman, G. D. 1982. The mountain pine beetle - identification, biology, cause of outbreaks and entomological research need. In D. M. Shrimptom (ed.). Proceedings of the Joint Canada/USDA Workshop on mountain pine beetle related problems in western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, p. 7-12.

Amman, G. D. 1982. Characteristics of mountain pine beetle reared in four pine hosts. Env. Entomol. 11:590-3.

ABSTRACT

Mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), obtained from naturally infested lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were reared in four common hosts: ponderosa pine, *P. ponderosa* Lawson; western white pine, *P. monticola* Douglas; whitebark pine, *P. albicaulis* Engelmann; and lodgepole pine. Emerging beetles were collected daily, counted, and sexed, and pronotal width was measure.

Significant differences in brood production, size of female beetles, and developmental rate, but not sex ratio, occurred among hosts. Differences were not all associated with the same species of tree. However, the results indicate that, overall, lodgepole pine is the poorest, and ponderosa pine is the best, of the four hosts for mountain pine beetle.

Amman, G. D. 1983. Strategy for reducing mountain pine beetle infestations with ponderosa pine trap logs. USDA For. Serv. Res. Note INT-338, 3 pp.

ABSTRACT

Mountain pine beetle were strongly attracted to ponderosa pine logs in decks. Of 283 logs cut in June and July and placed in decks, 74.9 percent became infested by mountain pine beetles. These observations suggest that ponderosa pine trap logs cut before beetle flight could attract a large proportion of beetles in a stand. The infested logs then could be removed to reduce the beetle population in the area.

Amman, G. D. 1983. A test of lodgepole pine hazard rating methods for mountain pine beetle infestation in southeastern Idaho. In L. Safranyik (ed.). The role of the host in the population dynamics of forest insects. Proc. IUFRO Conf., Banff, Alberta, Can., pp. 186-200.

ABSTRACT

Five stands of lodgepole pine in southeastern Idaho were rated for hazard to mountain pine beetle infestation by five methods. Losses to mountain pine beetle were correctly identified in three of the five stands using the age-dbh-elevation and PGR methods; in two of the five stands using grams of wood per square metre of foliage and PGR/SHR-phloem methods; and in none of the five stands using the SHR method. The SHR method was invalidated by low crown competition factor in all stands. Mountain pine beetle showed the usual strong preerence for trees of large diameter, but showed no consistent preference for trees of low PGR or low grams of wood per square metre of foliage. The less serious error of predicting moderate to high tree losses to mountain pine beetle when low losses occurred was associated with the age-dbh-elevation and grams of wood per square metre of foliage methods. The more serious error of predicting low tree losses to mountain pine beetle when losses were moderate to high was associated with the PGR, SHR, and PGR/SHR-phloem methods.

Amman, G. D. 1984. Mountain pine beetle (Coleoptera: Scolytidae) mortality in three types of infestations. Env. Entomol. 13:184-91.

ABSTRACT

Populations of mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), in lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were sampled at three heights within trees in endemic, epidemic, and postepidemic infestations. Eight mortality factors were evaluated: competition within and between broods, parasites, predators, pathogens, winter temperature, drying of the phloem, pitch, and unexplained mortality. Beetle survival was significantly greater ($P < 0.01$) in endemic (3.7%) than in epidemic (1.4%) and postepidemic (0.5%) infestations. Survival did not differ ($P > 0.05$) by height in trees. Parasites and predators accounted for 8, 33, and 4% of total mountain pine beetle losses in endemic, epidemic, and postepidemic infestations, respectively. *Medetera* (13%) and woodpeckers (15%) accounted for the greatest amount of predation, and this occurred during epidemic infestations. Most parasites and predators showed the typical density-dependent response. Clerids were the single exception, taking a greater proportion of beetles in endemic infestations, thus suggesting a role by clerids in keeping mountain pine beetle populations at an endemic level. However, clerids accounted for only 0.9% of beetle losses.

Amman, G. D. 1986. Dynamics of 1-year and 2-year life cycle populations of mountain pine beetle and related tree losses. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 37-50.

Amman, G. D. and B. H. Baker. 1972. Mountain pine beetle influence on lodgepole pine stand structure: an analysis of treated and untreated stands. J. For. 70:204-9.

ABSTRACT

Efforts to control populations of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in lodgepole pine (*Pinus contorta* Dougl.) were evaluated from tree diameter distributions within treated and untreated stands. Beetle populations, where infestation period was complete, declined in approximately the same number of years, and lodgepole pine survival in the two types of stands was comparable. However, suppression measures did slow the rate of tree mortality in two stands still under attack. Mixed stands of up to 36 percent trees of other species were proportionally as susceptible to beetle infestation as those having less than 10 percent trees of other species. Survival increased with elevation, apparently because of adverse effect of temperature on beetles.

Amman, G. D. and W. E. Cole. 1983. Mountain pine beetle dynamics in lodgepole pine forests. Part II. Population dynamics. USDA For. Serv. Gen. Tech. Rept. INT-145, 59 pp.

ABSTRACT

Much of this work is original research by the authors. However, published literature on the taxonomy, biology, and population dynamics of the beetle are reviewed primarily as they occur in epidemic beetle populations in lodgepole pine forests. Lodgepole pine tree characteristics such as size and phloem thickness have a strong influence on beetle survival, size, sex ratio, and genotype. Of the many mortality factors acting upon the beetle population alone or in combination, none regulate the population before severe damage occurs to stands of lodgepole pine. These findings demonstrate that the mountain pine beetle is food regulated.

Amman, G. D., B. H. Baker and L. E. Stipe. 1973. Lodgepole pine losses to mountain pine beetle related to elevation. USDA For. Serv. Res. Note INT-171, 8 pp.

ABSTRACT

Mortality caused by the mountain pine beetle was related inversely to elevation and ranged from less than 1 to 17 percent of the lodgepole pine trees 4 inches d.b.h. and larger. Mortality of trees 9 inches d.b.h. and larger (those most often infested by mountain pine beetle), ranged from 2 percent of the stems or 0.8 percent of the basal area at the highest elevation to 36.5 percent of the stems or 36 percent of the basal area at the lowest elevation. Climate probably is the single most important factor accounting for variation in mortality of lodgepole pine at the different elevations because of its effect on the biology of the beetle.

Amman, G. D. and M. D. McGregor. 1985. The beetle: behavior, biology, and life cycle. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp 2-7.

Amman, G. D. and M. D. McGregor. 1985. Assessing stand hazard and risk: hazard rating and predicting tree loss in unmanaged stands. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 29-30.

Amman, G. D., M. D. McGregor, D. B. Cahill and W. H. Klein. 1977. Guidelines for reducing losses of lodgepole pine to mountain pine beetle in unmanaged stands in the Rocky Mountains. USDA For. Serv. Gen. Tech. Rept. INT-36, 19 pp.

ABSTRACT

These guidelines are based on ecological relationships of the beetle and its host. They are applicable to unmanaged stands. In these stands, beetles show a strong preference for lodgepole pine of large diameter and 80 years of age or older. Stands at low elevations suffer the greatest losses to beetle infestation. At low elevations, climate is optimal for brood survival; the cool climate of high elevations has an adverse effect on survival of the beetle. These factors--tree diameter, tree age, and stand location--are used to predict stand risk to beetle infestation.

Measures can be taken to prevent or reduce losses to the beetle. Where timber production is the primary use of the land, large high-risk trees can be removed by partial cutting techniques. However, patch cutting or clearcutting should be used where most trees are in large-diameter classes and in stands where residual trees would not be numerically adequate nor physically vigorous should partial cutting techniques be used. Essentially, a "do nothing" policy is recommended where recreation values predominate or where noncommercial forests exist. Trees of high value in campgrounds, picnic areas, and near summer and permanent homesites can be protected with chemical sprays that prevent successful beetle infestation.

Amman, G. D., M. D. McGregor and R. E. Dolph, Jr. 1985. Mountain pine beetle. USDA For. Serv., Forest Insect and Disease Leaflet 2, 11 pp.

Amman, G. D. and V. E. Pace. 1976. Optimum egg gallery densities for the mountain pine beetle in relation to lodgepole pine phloem thickness. USDA For. Serv. Res. Note INT-209, 8 pp.

ABSTRACT

Laboratory studies were conducted to determine optimum densities of egg galleries constructed by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) phloem of different thickness. Beetle production per unit area of lodgepole pine bark occurred at egg gallery densities over 2.4 m per 30.4 $cm^2$ with greater production obtained from thick phloem. Beetle production began to flatten at

about 2.1 m per 30.4 $cm^2$ in thin phloem and at 2.4 m in thick phloem. Production curves remained asymptotic to 3 m of egg gallery per 30.4 $cm^2$ the upper limit observed in this study. Beetle production per unit of egg gallery length was highest at the lowest gallery density in all phloem thicknesses. As expected, beetle production was greatest in thick phloem.

The largest brood adults emerged from thick phloem at all egg gallery densities. But, for thick and thin phloem alike, size declined after egg gallery densities exceeded about 1.5 m per 30.4 $cm^2$. Beetles were significantly smaller in thin phloem, even at the lowest gallery densities. Male survival was proportionately lower in thin phloem than in thick phloem. The smaller size of beetles and lower survival of males suggest a qualitative difference between thin and thick phloem that may be important in dynamics of mountain pine beetle populations.

Amman, G. D. and L. A. Rasmussen. 1969. Techniques for radiographing and the accuracy of the X-ray method for identifying and estimating numbers of the mountain pine beetle. J. Econ. Entomol. 62:631-4.

ABSTRACT

X-ray-exposure curves using 2 kilovoltages (kv) were developed for lodgepole pine slabs of different thickness and moisture content. X-ray exposure at 25 kv for a wood-and-bark slab containing 30% moisture varied, for example, from 4.5 milliampere minutes (mam) for a 1.5-inch-thick slab to 20 mam for a 3-inch-thick slab. The relationship between wood-and-bark thickness and optimum exposure became increasingly curvilinear as moisture content increased. In contrast, X-ray exposure at 45 kv for wood and bark containing 30% moisture varied from 0.4 mam for a 1.5-inch-thick slab to 1.25 mam for a 3-inch-thick slab. At 45 kv the relationship between wood-and-bark thickness and exposure remained approximately linear for all moisture contents.

Identifications and estimates of numbers of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were obtained from radiographs. Radiographs obtained using an exposure of 25 kv proved to be best for identifying and determining numbers of small and medium-sized larvae. Radiographs obtained using either 25 or 45 kv could be used with about equal accuracy for identifying and estimating numbers of large larvae, pupae, and callow adults. Errors in identification and in estimating numbers of beetles from radiographs obtained using an exposure of 25 kv were less than 10% of the mean and seem acceptable for population studies of bark beetles.

Amman, G. D. and L. A. Rasmussen. 1974. A comparison of radiographic and bark-removal methods for sampling of mountain pine beetle populations. USDA For. Serv. Res. Pap. INT-151, 11 pp.

ABSTRACT

Populations of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were sampled by both radiographic and bark-removal methods in standing lodgepole pine, *Pinus contorta* Douglas. Estimates of live beetle numbers based on the two methods were comparable. However, the radiographic method is not recommended for field sampling because it is more costly and the causes of beetle mortality usually cannot be determined. In addition, beetle populations in areas radiographed were adversely affected, probably because of drying of wood and bark, which resulted in erroneous estimates of brood survival and distorted sex ratios.

Amman, G. D. and L. Safranyik. 1985. Insects of lodgepole pine: impacts and control. In D. M. Baumgartner, R. G. Krebill, J. T. Arnott and G. F. Weetman (eds.). Symp. Proc., Coop. Ext., Wash. State Univ., pp. 107-24.

ABSTRACT

Of approximately 240 species of insects that feed on lodgepole pine, 35 are considered pests or potential pests. Nine insect species cause serious damage in periodic, local infestations and one species, the mountain pine beetle, causes catastrophic losses in repeated outbreaks over most of its distributional range. Stand management offers the best possibility for reducing losses. Seed and cone insects do not extensively affect seed production; nursery stock can be protected through cultural practices and pesticide treatments. Several insects affecting young stands cause reduced height growth and permanent crooks in stems. Defoliating insects, such as the lodgepole needle miner and pine sawflies, usually infest trees of all ages and cause growth loss and some mortality during severe outbreaks. Bark beetles, especially the mountain pine beetle, pose the most serious threat to lodgepole pine management.

Anderson, L. S., A. A. Berryman, D. G. Burnell, W. H. Klein, E. L. Michaelson, A. R. Stark. 1976. The development of predictive models in the lodgepole pine - mountain pine beetle ecosystem. In R. L. Tummala, D. L. Haynes and B. A. Croft (eds.). Modeling for pest management: concept, techniques and applications. Mich. State Univ. Press, pp. 149-64.

Andrews, R. J. 1982. Mountain pine beetle infestation. Manning Provincial Park. Pac. For. Res. Cent., Can. For. Serv., Victoria, Pest Rept., March 1982, 3 pp.

Anon. 1982. Thinning to prevent mountain pine beetles in lodgepole and ponderosa pine. Oregon St. Univ. Ext. Serv.; Ext. Circ. 1106, 4 pp.

Atkins, M. D. 1966. Behavioral variation among scolytids in relation to their habitat. Can. Entomol. 98:285-8.

ABSTRACT

Most scolytids occupy temporary habitats. Migration, therefore, forms an important part of adult behavior. Since the extent of migratory movement is positively correlated with the degree of impermanence of the species' habitat, differences in the behavior associated with migration must be expected to occur between species. Furthermore, the behavior of individuals must change in relation to changes in physiology associated with migration and reproduction. These changes have been demonstrated in laboratory studies, and the results suggest that the phenomenon of secondary attraction observed among scolytids may have evolved in conjunction with their utilization of transitory habitats.

Averill, R. D. 1978. Simulating yields from ponderosa pine stands attacked by the mountain pine beetle in the Black Hills. USDA For. Serv. (DRAFT)

Averill, R. D. 1978. Mountain pine beetle management strategy. USDA For. Serv., Rocky Mtn. Reg., Rept., 18 pp.

Averill, R. D., J. E. Gunter, C. K. Lister, and D. H. Sonnen. 1977. Guidelines for estimating the economic benefits of mountain pine beetle control projects. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-11, 30 pp.

Averill, R. D. and D. Leatherman. 1975. Post control evaluation, Estes Park, Colorado, September, 1974. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-3, 6 pp.

Averill, R. D. and D. Leatherman. 1983. Biological Evaluation. Mountain pine beetle in Grand County, Colorado - 1983. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-83-6, 7 pp.

Baker, B. H. 1968. The use of "buildup ratios" as indicators of mountain pine beetle population trends. USDA For. Serv., Int. Mtn. Reg., Rept., 6 pp.

Baker, B. H., G. D. Amman and G. C. Trostle. 1971. Does the mountain pine beetle change hosts in mixed lodgepole and whitebark pine stands? USDA For. Serv. Res. Note INT-151, 7 pp.

ABSTRACT

Lodgepole pine (*Pinus contorta* Dougl.) and whitebark pine (*P. albicaulus* Engelm.) losses attributable to the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) were compared in three study areas within two mixed species stands at high elevations. Results suggest that this beetle displays host specificity for the tree species in which it completed larval development because extensive mortality in one host species did not result in comparable mortality in an associated species.

* Ballard, R. G., M. A. Walsh and W. E. Cole. 1980. Beetle kill in lodgepole pine. Utah Sci. (Fall 1980):78-81.

Ballard, R. G., M. A. Walsh and W. E. Cole. 1982. Blue-stain fungi in the xylem of lodgepole pine: a light-microscope study on extent of hyphal distribution. Can. J. Bot. 60:2334-41.

ABSTRACT

In midsummer mountain pine beetles emerge from lodgepole pine trees and fly to unattacked trees. While chewing vertical egg galleries in the inner bark of the tree, they inoculate into it a blue-stain fungus complex. Initially, the fungi are confined to the beetle frass of the egg gallery, but they soon grow into the sapwood. The fungi spread radially via the parenchyma of the xylem rays. Once established in the xylem rays, fungal hyphae move into the tracheids of the axial water-conducting system. Here they occlude bordered-pit pairs and occasionally the entire lumen of the cell. Fungal hyphae also attack and destoy resin-duct epithelial cells. This may result in release of resin into surrounding tissues. Destruction of storage and water-conducting tissues in the tree trunk is detrimental to renewed shoot tip expansion the following spring.

Ballard, R. G., M. A. Walsh and W. E. Cole. 1984. The penetration and growth of blue stain fungi in the sapwood of lodgepole pine attacked by mountain pine beetle. Can. J. Bot. 62:1724-9.

ABSTRACT

The growth of blue-stain fungi was investigated in naturally blue-stained lodgepole pine (*Pinus contorta* var. *latifolia* Engelm) sapwood. Events occurring at the leading edge of hyphal penetration were studied. Fungi are initially confined to the sapwood rays. Hyphae readily penetrate the primary cell walls of ray parenchyma cells and proliferate within. Hyphae also grow freely in the region of the middle lamella of the rays. Host cell walls are breeched mechanically by a penetration peg originating from an appressoriumlike structure. Eventually, hyphae enter tracheids by penetrating the primary cell walls of pinoid, half-bordered pit pairs. Within the tracheid, fungal hyphae grow in a longitudinal fashion, branching infrequently. Hyphae may pass from tracheid to tracheid via bordered pit pairs. Ensuing water stress and eventual tree death is discussed in light of histological evidence presented.

Barger, R. L. 1982. Research needs: Engineering, utilization economics, socioeconomics, and fire. In D. M. Shrimptom (ed.). Proceedings of the joint Canada/USDA workshop on the mountian pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 24-28.

Baumgartner, D. M. 1975. Management of lodgepole pine ecosystems. Wash. State Univ., Coop. Ext. Serv., Pullman, WA.

* Baumhofer, L. G. 1933. Bark beetle situation in the Roosevelt National Forest. USDA For. Serv.

Beal, J. A. 1939. The Black Hills beetle, a serious enemy of Rocky Mountain pines. USDA Farm. Bul. 1824, 22 pp.

Beal, J. A. 1943. Relation between tree growth and outbreaks of the Black Hills beetle. J. For. 41:359-66.

ABSTRACT

During the past decade losses of ponderosa pine resulting from the work of the Black Hills beetle have been exceptionally heavy. In an attempt to determine the cause of these outbreaks an analysis of the growth rate of trees, as affected by precipitation, was made. Although most of the outbreaks occurred during periods of deficient moisture and relatively poor tree growth, the exceptions strongly indicate that other factors are sometimes fully as important as these.

* Beal, J. A. and D. DeLeon. 1938. A study of the Black Hills beetle in Southeastern Wyoming and Central Colorado, summer of 1937. USDA For. Serv. Rocky Mtn. Sta., Fort Collins, CO.

* Bedard, W. D. 1931. New facts regarding the biology of the mountain pine beetle in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1933. Additional information concerning the biology and habits of the mountian pine beetle in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1933. The relation of parasites to mountain pine beetle control in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1937. A study of mountain pine beetle infestations in western white pine, 1936 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1937. The effect of tempering as a means of increasing cold-hardiness upon the lipid and moisture content of mountain pine beetle larvae. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1938. Preliminary report concerning the relationship between mountain pine beetle infestations and types of host materials, 1937 investigations. USDA Bur. Entomol., For. Insect Lab., Coeur d'Alene, ID.

* Bedard, W. D. 1938. Preliminary report relative to biological factors in the control of the mountain pine beetle, 1937 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1938. A study of mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID, 65 pp.

* Bedard, W. D. 1938. The relations of lipid and moisture content to cold-hardiness of mountain pine beetle larvae. USDA Bur. Entomol., Coeur d' Alene, ID.

* Bedard, W. D. 1938. Tree injection as a control of the mountain pine beetle in western white pine, 1938 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

Bedard, W. D. 1938. Control of the mountain pine beetle by means of chemicals. J. For. 36:35-40.

* Bedard, W. D. 1939. The relationship between mountain pine beetle infestations and types of host materials, 1938 investigations. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1939. Biological factors in control of the mountain pine beetle. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1939. A study of mountain pine beetle infestations in western white pine. USDA Bur. Entomol, Coeur d'Alene, ID, 47 pp.

* Bedard, W. D. 1939. An investigation of the apparent effect of road construction on mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1940. A summary of four years' exploratory study of mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. 1940. Some factors influencing mountain pine beetle (*Dendroctonus monticolae* Hopk.) populations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID

* Bedard, W. D. 1942. An experiment in fostering native insect enemies of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.). USDA Bur. Entomol., Coeur d'Alene, ID.

* Bedard, W. D. and T. T. Terrell. 1939. A method for predicting the trend of mountain pine beetle infestations in western white pine. USDA Bur. Entomol., Coeur d'Alene, ID.

* Beeson, T. 1971. Testing covering with polyethylene sheeting for control of *Dendroctonus ponderosae* in Boulder County, Colorado, 1971. Colo. State For. Serv., Longmont, CO.

Bennett, D. D. 1979. Pilot survey to measure annual mortality caused by the mountain pine beetle in lodgepole pine on the Beaverhead, Gallatin and Flathead Forests in 1978. USDA For. Serv., Northern Reg., Rept. No. 79-12, 4 pp.

Bennett, D. D., W. E. Bousfield, M. D. McGregor and K. E. Gibson. 1980. Evaluation of multistage sampling techniques to measure lodgepole pine mortality caused by mountain pine beetle in Montana, 1979. USDA For. Serv., Northern Region, Rept. No. 80-13, 11 pp.

ABSTRACT

A pilot survey was conducted to evaluate the effectiveness of using multistage sampling techniques to measure annual and cumulative mortality on a State-wide basis with acceptable statistical reliability, timeliness, and cost.

Within the State of Montana, aerial surveys showed about 986,000 acres of lodgepole pine infested with mountain pine beetle. This area was stratified into three intensity classes. Initial stratification, from 1979 aerial sketchmap surveys, was followed by large-scale (1:6000) aerial photography (on a sample basis), photo interpretation, and ground truth measurements. Photo plots were selected by a systematic random process for each stratum. Ground truth plots were chosen by probability proportional to size (pps).

Estimates of 1978 attacked lodgepole pine (faders) were 11.6 million trees, representing a volume of 161.4 million cubic feet. Relative sampling errors were 9.8 and 16.5 percent for numbers of faders and volume, respectively. The total number of standing dead was 33.4 million trees, with a volume of 517 million cubic feet. The survey required 257 man-hours at a cost of $43,500.

Bennett, D. D. and M.D. McGregor. 1980. A demonstration of basal area cutting to manage mountain pine beetle in second-growth ponderosa pine. USDA For. Serv., Northern Reg. Rept. No. 80-16, 2 pp.

Bentz, B. J. 1984. Phenetic and phylogenetic relationships among *Dendroctonus* (Coleoptera: Scolytidae) bark beetles. Univ. of Id., College of For. Res. M.S. Thesis.

ABSTRACT

Molecular genetic relationships among 10 species of *Dendroctonus* bark beetles were assessed using electrophoretic data from 18 gene loci. Cluster and distance Wagner analysis of these data showed a high level of similarity between *D. pseudotsugae* Hopkins and *D. simplex* LeConte, *D. valens* LeConte and *D. terebrans* (Olivier), and *D. adjunctus* Blandford and *D. approximatus* Dietz. These groupings correspond generally to groups identified in earlier studies using anatomical, cytogenetic, and behavorial characteristics. The distance Wagner tree indicated that *D. rufipennis* (Kirby), *D. adjunctus* and *D. approximatus* are the most primitive speiceds. *D. valens, D. terebrans, D. simplex, D. pseudotsugae,* and *D. frontalis* Zimmermann appear to be the most evolutionarily advanced of the species studied.

Bentz, B. J. and M. W. Stock. 1986. Phenetic and Phylogenetic relationships among ten species of Dendroctonus bark beetles (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 79:527-34.

Berryman, A. A. 1972. Resistance of conifers to invasion by bark beetle-fungus associations. Bio Science 22:598-602.

Berryman, A. A. 1974. Dynamics of bark beetle populations: Towards a general productivity model. Env. Entomol. 3:579-85.

ABSTRACT

The components of productivity (offspring produced per parent) in bark beetle populations are defined as multiplication and survival. Data from the literature are used to formulate simple models relating these components to initial density in infested trees. A simple monotonic exponential decay function is proposed for describing the multiplication component, although data for validation are scarce. A humpbacked function is proposed for the survival component. This model combines 2 equations, one expressing survival as a direct function of attack density, and the other survival as an inverse function of density.

Berryman, A. A. 1975. Management of mountain pine beetle populations in lodgepole pine ecosystems: A cooperative interdisciplinary research and development project. In D. M. Baumgartner (ed.). Management of lodgepole pine ecosystems. Coop. Ext. Serv., Col. Agr. Wash. State Univ., Pullman, WA, pp. 627-50.

ABSTRACT

The objectives, organization, participating institutions, and scientists of a cooperative research project, aimed at developing a pest management system for the mountain pine beetle in lodgepole pine stands, are presented. The conceptual framework on which the management system is being built is discussed in relation to (a) measurement, description, and modeling of the dynamic insect population, (b) description and analysis of the socioeconomic impact of the insect on the forest resource, (c) analysis and decision-making procedures for optimizing management alternatives.

Berryman, A. A. 1976. Theoretical explanation of mountain pine beetle dynamics in lodgepole pine forests. Env. Entomol. 5:1225-33.

ABSTRACT

Sample data from 215 infested lodgepole pines from 11 separate locations in the United States and Canada were analyzed to determine the relative effect of the measured variables on mountain pine beetle emergence density (production). From this analysis a model was developed which expresses production as a function of attack density and basic habitat suitability. The measured variables having the most influence on basic habitat suitability were lodgepole pine phloem thickness, cortical resin canals, host resistance, and predation by woodpeckers. Host resistance was also found to influence the intensity of attack. A theoretical model was constructed to examine the relative effects of lodgepole pine phloem thickness, and resistance to attack, on the dynamics of the beetle population. Analysis indicated that mountain pine beetle outbreaks are triggered by rapid declines in stand resistance resulting from climatic disturbances, insect defoliation, etc.

Berryman, A. A. 1978. A synoptic model of the lodgepole pine/mountain pine beetle interaction and its potential application in forest management. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 98-105.

ABSTRACT

A simple graphical model is presented which displays the risk and intensity of mountain pine beetle (*Dendroctonus ponderosae* Hopkins)-caused timber mortality in terms of average stand phloem thickness, stand resistance to attack, and climate. The model provides a tool to help the forest manager understand the interaction between the beetle and the stand and, when fit to data from lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stands, can be used to predict the likelihood of mountain pine beetle epidemics in real or simulated stands and to evaluate management alternatives.

Berryman, A. A. 1979. Dynamics of bark beetle populations: Analysis of dispersal and redistribution. Bull. Soc. Ent. Suisse. 52:227-34.

ABSTRACT

The density-dependent bark beetle productivity model proposed by BERRYMAN (1974) is extended to include the effects of survival during dispersal and redistribution on new hosts. The effects of varying food abundance and dispersal, particularly immigration, on the dynamic behavior of the model are evaluated.

Berryman, A. A. 1980. General constructs for risk decision models. Proc. Soc. Am. For., pp. 123-8.

ABSTRACT

The behavior of forest pest populations can usually be described as cyclic or eruptive based on the regularity of the outbreak occurrences. Risk classification models for cyclic pests can be designed if the single critical parameter, the maximum rate of increase of the pest (R), can be defined as a function of measurable stand and site variables. Eruptive pests have more complex behavior becuase their population systems evoke threshold phenomena. Risk classification models for these pests can be designed if the two critical parameters, the potential pest population density (N), and the effectiveness of the control mechanism (C), can be defined as functions of measurable stand and/or site variables, and if the threshold can be located empirically.

Risk classification models based on the theoretical considerations discussed in this paper are applicable over a wider range of the conditions than conventional models based entirely on empirical data. They also provide a bsis for evaluating management strategies aimed at reducing the risk of pest outbreaks and for explaining the dynamic properties of forest insect systems to the forest manager (e.g., see Berryman 1978c).

Berryman, A. A. 1982. Mountain pine beetle outbreaks in Rocky Mountain lodgepole pine forests. J. For. 80:410-3.

ABSTRACT

Recent research provides a new perspective on the causes of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreaks in lodgepole pine (*Pinus contorta* Douglas *var. latifolia* Engelm.) forests of the Rocky Mountain. The most explosive outbreaks seem to originate in stands of low current vigor but having a high percentage of trees with thick phloem. Because large beetle populations can ovecome the resistance of relatively vigorous trees, once an outbreak has startd in a particular locality it often spreads over vast areas. On this interpretation of outbreak causation, methods for anticipating where and when outbreaks will occur have been developed to help the manager set priorities for stand treatment. Treatments can also be tested on computer models of stand growth linked to beetle population models. In general, silviculture aimed at maintaining tree vigor seems to offer the most promise for preventing outbreaks.

Berryman, A. A. 1982. Biological control, thresholds, and pest outbreaks. Env. Entomol. 11:544-9.

ABSTRACT

Pest populations are frequently regulated below their potential levels of abundance by natural enemies, host resistance, or other biological interactions. However, if these regulating processes operate imperfectly, or are intolerant to variations in pest density, then we may observe periodic outbreaks of the pest. In effect, intolerant regulating processes create thresholds separating distinct dynamic behaviors, usually referred to as endemic and epidemic behaviors. If threshold functions can be defined in terms of measurable system variables, they offer a powerful approach for evaluating the risk of epidemics in managed ecosystems. Methods for defining threshold functions and constructing risk decision models are discussed.

* Berryman, A. A. 1982. Population dynamics of bark beetles. In J. B. Mitton and K. B. Sturgeon (eds.). Bark beetles of North American conifers - a system for the study of evolutionary ecology. Univ. Texas Press, Austin, pp. 264-314.

Berryman, A. A. 1983. Defining the resilience thresholds of ecosystems. In W. K. Lauenroth, G. V. Skogerboc and M. Flug (eds.). Analysis of ecological systems: State-of-the-art in ecological modeling. Elsevier Sci. Publ. Co., Amsterdam, pp. 57-60.

ABSTRACT

Resilience thresholds define the unstable boundaries separating distinct behavioral domains of ecological systems. Because they represent transient system states, however, they are difficult to define empirically. Models are utilized to define the resilience properties of a bark beetle-conifer system, to identify the unstable threshold, and to develop risk assessment methods.

* Berryman, A. A. 1984. Threshold theory and its applications to pest population management. In G. R. Conway (ed.). Pest and pathogen control: Strategic, tactical, and policy models. Int. Series on Appl. Syst. Anal., 13, John Wiley and Sons, New York, pp. 40-57.

Berryman, A. A., G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). 1978. Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For. Wild, and Range Exp. Sta., Univ. of Idaho, Moscow, 224 pp.

Berryman, A. A., B. Dennis, K. F. Raffa and N. C. Stenseth. 1985. Evolution of optimal group attack, with particular reference to bark beetles (Coleoptera: Scolytidae). Ecol. 66:898-903.

ABSTRACT

A general model for the benefits and costs of group attack by small predators that kill large prey was developed, and provided support for the hypothesis that bark beetles infesting pine trees have evolved group attack behavior that maximizes individual fitness. The model also provides a bsis for evaluating the conditions under which social hunting behavior is likely to evolve, and provides insights on the population dynamics of animals that hunt in groups.

Berryman, A. A. and N. C. Stenseth. 1984. Behavioral catastrophes in biological systems. Behav. Sci. 29:127-37.

ABSTRACT

Catastrophic behavior of systems of animal organism populations is analyzed in relation to energy inputs into the system. In unconstrained systems, steady state equilibrium behavior is only possible if energy use rates equal input rates, while catastrophic explosions and collapses can occur when energy is drawn from an accumulated pool. In constrained systems, where negative feedback mechanisms regulate proliferation below the energy input rate, catastrophic behavior can occur if the regulative mechanisms saturate or are weakened by external stresses. Such systems are often characterized by breakpoints or thresholds, and we may observe single stable point-equilibria, dual stable point-equilibria, metastable point-equilibria, or cyclic-equilibria.

Application of theory to management problems is addressed, with particular reference to an insect pest infesting coniferous forests. Because the risk of undesirable behavior (pest outbreaks) is proportional to the distance from the unstable breakpoint (outbreak threshold), risk can be estimated if the threshold function is known. In the example, the threshold is approximated as a function of forest variables which determine insect numbers and tree resistance to infection.

Berryman, A. A. and N. C. Stenseth and D. J. Wollkind. 1984. Metastability of forest ecosystems infested by bark beetles. Res. Popul. Ecol. 27:13-29.

ABSTRACT

A simple two-species differential equation model is used to investigate the intrinsic metastability of forest ecosystems subjected to bark beetle infestations. We demonstrate that only one globally stable node or limit cycle is likely under biologically plausible conditions, but that, in the former case, this equilibrium is very sensitive to external perturbation.

Berryman, A. A. and R. W. Stark. 1985. Assessing the risk of forest insect outbreaks. Z. ang. Entomol. 99:199-208.

ABSTRACT

Destructive outbreaks of forest pests are classified as gradient, cyclical or eruptive. The first of two types of outbreaks (gradient,

cyclical) are generated by stand and site conditions conducive to the reproduction and survival of the pest or stressfull for the host plant(s). In these cases, outbreak probability, or risk, can be assessed with unidimensional risk equations. Outbreaks of the third type, the eruptive pests, are more difficult to predict because the density of the pest plays a critical role in initiating outbreaks in particular stands. Risk assessment models for these pests require a two-dimensional structure that integrates stand, site and insect numbers. We discuss methods for developing risk assessment models for eruptive pests using, as an example, mountain pine beetle populations infesting lodgepole pine stands.

Berryman, A. A. and R. W. Stark. 1985. Assessing the risk of lodgepole pine stand destruction by pests. In D. M. Baumgartner, R. G. Krebill, J. T. Arnott and G. F. Weetman (eds.). Lodgepole pine - the species and its management. Symp. Proc., Coop. Ext., Wash. State Univ., pp. 164-9.

ABSTRACT

Destructive outbreaks of forest pests are classified as gradient, cyclical or eruptive. The first of two types of outbreaks (gradient, cyclical) are generated by stand and site conditions conducive to the reproduction and survival of the pest or stressfull for the host plant(s). In these cases, outbreak probability, or risk, can be assessed with unidimensional risk equations. Outbreaks of the third type, the eruptive pests, are more difficult to predict because the density of the pest plays a critical role in initiating outbreaks in particular stands. Risk assessment models for these pests require a two-dimensional structure that integrates stand, site and insect numbers. We discuss methods for developing risk assessment models for eruptive pests using, as an example, mountain pine beetle populations infesting lodgepole pine stands.

Beveridge, Ron and Ralph Thier. 1982. Hazard: A computer program to rate potential for mountain pine beetle activity in lodgepole and ponderosa pine stands in the Intermountain Region. USDA For. Serv., Int. Mtn. Reg., Rept. No. 82-11, 7 pp.

ABSTRACT

A computer program, HAZARD, which utilizes TMIS data bases to rate susceptibility of lodgepole and ponderosa pine stands to mountain pine beetle attack is now available for use by forest managers. Use of the program is described herein.

* Billings, R. F. 1970. Parasites and predators of *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae) in ponderosa pine. M.S. Thesis, Oregon St. Univ., Corvallis

* Billings, R. F. 1974. Host selection and attack behavior of *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae) in ponderosa pine of eastern Washington. Ph.D. thesis, Univ. of Wash., Seattle.

Billings, R. F. and R. I. Gara. 1975. Rhythmic emergence of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) from two host species. Ann. Entomol. Soc. Am. 68:1033-6.

ABSTRACT

Emergence of adult *Dendroctonus ponderosae* Hopkins from ponderosa pine *(Pinus ponderosa* Laws.) and western white pine (*P. monticola* Dougl.) exhibited distinct host-specific patterns under field conditions that appeared closely correlated with ambient temperatures in the latter host species but not in the former. The lower temperature threshold for beetle emergence was ca. 16°C. Diel periodicities in emergence from both host species also prevailed under conditions of constant temperature and light, providing evidence of an endogenous rhythm. Ratios of 1 male to 3 females, observed during the first week of seasonal emergence from ponderosa pine, appeared to change in favor of males as the season progressed. A more constant 1:2 male to female ratio was maintained in broods emerging from western white pine.

Billings, R. F., R. I. Gara and B. F. Hruthfiord. 1976. Influence of ponderosa pine resin volatiles on the response of *Dendroctonus ponderosae* to synthetic *trans*-verbenol. Env. Entomol. 5:171-9.

ABSTRACT

The synergistic effect of various host factors on the response of in-flight populations of *Dendroctonus ponderosae* Hopkins emerging from *Pinus ponderosa* Laws. to the aggregation pheromone *trans*-verbenol was quantified in a series of replicated field bio-assays. Synthetic formulations of *trans*-verbenol, although largely inactive alone, attracted beetles when deployed with certain host terpenes, particularly myrcene and terpinolene. Freshly extracted ponderosa

pine oleoresin in combination with *trans*-verbenole as significantly more attractive to beetle populations, particularly to females, than were pheromone complexes containing single monoterpenes of the composite monoterpene fraction of oleoresin (distilled oil). When tested with *trans*-verbenol on traps without replacement, fresh resin samples lost their superior attractiveness within 1 day; paralleled those on pheromone traps baited with distilled oils. The qualitative monoterpene composition of fresh resin, however, did not appear to change with short term exposure or during the steam distillation process. In combination, these findings suggested the presence of host-produced chemical messengers other than monoterpenes in oleoresin which are disproportionately attractive to ♀ *D. ponderosae*, the host selecting sex. Analysis of resin samples by gas chromatography and mass spectrometry led to the constituent which may contribute to the superior field attractiveness of fresh resin. The need to further investigate the role of non-terpene host volatiles in bark beetle host selection is stressed.

Blackman, M. W. 1931. The Black Hills beetle (*Dendroctonus ponderosae* Hopk.). NY State Col. For. Tech. Pub. 36, Vol. 4, 97 pp.

* Blackman, M. W. 1938. Report on an examination of *Dendroctonus ponderosae* and *D. monticolae*. USDA Bur. Entomol. and Plant Quar., Washington, DC.

Borden, J. H. 1982. Secondary attraction in the Scolytidae: An annotated bibliography. Simon Fraser Univ., Dept. of Bio. Sci., Pest Mgmt. Papers No. 26, 185 pp.

Borden, J. H. 1984. Semiochemical-mediated aggregation and dispersion in coleoptera. In Insect Communication. T. Lewis (ed.). Academic Press, London, pp. 123-49.

Borden, J. H. 1986. Methods for use of semiochemicals against the mountain pine beetle, *Dendroctonus ponderosae*. In Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 79-86.

Borden, J. H., L. J. Chong, and M. C. Fuchs. 1983. Application of semiochemicals in post-logging manipulation of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). J. Econ. Entomol. 76:1428-32.

ABSTRACT

Lodgepole and ponderosa pines, *Pinus contorta* var. *latifolia* Engelm. and *P. ponderosa* Dougl. ex. Laws., respectively, in the interior of British Columbia were baited with the semiochemicals myrcene, *trans*-verbenol and *exo*-brevicomin to induce attack by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins. In one post-logging application, semiochemical baiting was effective in shifting the locus of a small infestation so that it could be cut and removed from the forest. In another application after a selective, sanitation-salvage cutting, semiochemical baiting was successful in concentrating a residual population in baited trees and trees surrounding them.

Borden, J. H., L. J. Chong, and T. E. Lacey. (In Press). Pre-logging baiting with semiochemicals for the mountain pine beetle, *Dendroctonus ponderosae,* in high hazard stands of lodgepole pine. For. Chron.

ABSTRACT

Baiting of trees with attractive semiochemicals prior to logging in three high hazard blocks of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) was effective in inducing attack by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) on baited trees and on surrounding unbaited trees. There was evidence for partial shifting of attack loci, concentration of dispersing beetles and containment of emergent beetles as a result of the baiting program. However, baiting was ineffective when the baits were within the understory canopy, and the baiting program did not cause a massive influx of beetles from infestations 75-200 m away from the baited blocks. Such baiting programs would be cost effective if they avoided the necessity of disposing of two attacked trees/ha outside of the baited blocks. They have the additional advantage of reducing the risk of future beetle attacks by removing beetles and their broods during logging of induced infestations.

Borden, J. H., L. J. Chong, K. E. G. Pratt, and D. R. Gray. 1983. The application of behavior-modifying chemicals to contain infestations of the mountain pine beetle, *Dendroctonus ponderosae*. For. Chron. 59:235-9.

ABSTRACT

Five replicates of paired forest blocks containing lodgepole pine, *Pinus contorta* var. *latifolia* Engelm., infested by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were chosen in the spring of 1982 in various interior British Columbia locations. Within the experimental block of each pair, one lodgepole pine every 50 m (4 trees/ha) was baited with the attractive semiochemicals myrcene, *trans*-verbenol and *exo*-brevicomin. The baiting program caused the attack in 1982 to be concentrated in and around the baited trees, whereas it was more dispersed in the control blocks. The overall ratio of 1982:1981 attacked trees was 2.5 in the baited blocks and 1.8 in the controls, suggesting that dispersal of beetles out of the baited blocks was inhibited. Baiting of trees with semiochemicals is recommended to contain infestations within prescribed boundaries when sanitation-salvage logging cannot be completed prior to mid-summer flight of emergent brood beetles.

Borden, J. h., J. E. Conn, L. M. Friskie, B. E. Scott, L. J. Chong, H. D. Pierce, Jr., and A. C. Oehlschlager. 1983. Semiochemicals for the mountain pine beetle, *Dendroctonus ponderosae*, in British Columbia: baited tree studies. Can. J. For. Res. 13:325-33.

ABSTRACT

Lodgepole pines, *Pinus contorta* var, *latifolia* Engelm., in three interior British Columbia locations were baited with six monoterpenes lone or combined, and various combinations of the beetle-produced volatiles *trans*-verbenol, *exo*-brevicomin, and 3-caren-10-ol. Trees baited with *trans*-verbenol, *exo*-brevicomin, and the monoterpene 3-carene sustained higher attack densities by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, and were surrounded by more attacked trees than trees baited with *trans*-verbenol and 3-carene or unbaited controls. Myrcene was apparently the best of six monoterpenes as synergist for *trans*-verbenol. 3-Caren-10-ol appeared to have some activity in an early test but did not prove to be an attractive pheromone in extensive studies. In a 17-ha portion of an infestation, treatment of 99 trees with 3-carene and *trans*-verbenol apparently caused a higher attack rate, resulting in 56.4% of the available green trees being attacked, as opposed to 22.3% of the available trees in the 14-ha unbaited area. These data as well as the high attack rates associated with trees which also had an *exo*-brevicomin bait suggest that semiochemicals could be used to contain *D. ponderosae* infestations and to attract beetles to lethal trap trees.

Borden, J. H., D. W. A. Hunt, D. R. Miller, and K. N. Slessor. (In press). Orientation in forest Coleoptera: an uncertain outcome of responses by individual beetles to variable stimuli. Oxford Univ. Press.

Borden, J. H. and T. E. Lacey. 1985. Semiochemical-based manipulation of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins: A component of lodgepole pine silviculture in the Merritt Timber Supply Area of British Columbia. Z. angew Entomol. 99:139-45.

ABSTRACT

The Merritt Timber Supply area in south-central British Columbia is taken as an example of a forest management unit in which large areas of mature and over-mature lodgepole pine are vulnerable to infestations of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Seventeen sites are described in which 2,132 semiochemical baits (myrcene, *trans*-verbenol and *exo*-brevicomin) were used in 1984 as a component of forest management operations to manipulate populations of the beetle. The principal applications of the semiochemical baits were to contain and concentrate infestations on baited trees prior to logging, and to mop up residual beetles in post-logging treatments.

* Borden, J. H. and E. Stokkink. 1971. Secondary attraction in Scolytidae: An annotated bibliography. Can. For. Serv., For. Res. Lab., Victoria, B.C., Inform. Rept. BC-X-57, 77 pp.

Boss, G. D. and T. O. Thatcher. 1970. Mites associated with *Ips* and *Dendroctonus* in Southern Rocky Mountains with special reference to *Iponemus truncatus* (Acarina:Tarsonemidae). USDA For. Serv. Res. Note RM-171, 7 pp.

ABSTRACT

No mites attacked any stage of the *Dendroctonus* beetles. Mites of the genera *Iponemus* Lindquist and *Digamasellus* Berlese were predaceous on the eggs of *Ips*. *Iponemus truncatus* (Ewing) females completed their life cycle in 8.7 days. Female mites overwintered in the egg niches of the beetles and fed on phloem sugar, bacteria, and yeast, but required predation on beetle eggs for reproduction. Each mite fed on one beetle egg and produced about 75 eggs.

Bousfield, W. E., M. D. McGregor and S. Kohler. 1973. Mountain pine beetle impact survey on the Ninemile District, Lolo National Forest, and surrounding state and private lands. USDA For. Serv. Northern Reg. Rept. No. 73-7, 4 pp.

ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae* Hopk., can be a serious pest of second-growth ponderosa pine stands. Infestations generally are associated with overstocked stands and continue until susceptible host material has been depleted. An infestation on the Lolo National Forest and surrounding State and private lands has existed in the Ninemile area since 1969. There are about 30,000 acres of pine type in the infestation, but only about 2,592 acres are within the heavy infested zone.

Brannan, C. F. 1948. Black Hills National Forest - 50th Anniversary. USDA For. Serv., Washington DC, 43 pp.

Brennan, J. A. 1982. The need for action. What is being done in the forests of Alberta and plans for the future. In D. M. Shrimptom (ed.). Proceedings of the joint Canada/USA workshop on the mountian pine beetle and related problems in Western North America. Can. For. Serv. Rept. BC-X-230, pp. 41-43.

* Briegleb, P. A. 1943. Growth of ponderosa pine by Keen tree class. USDA For. Serv. Res. Note 32, 15 pp.

* Brown, G. S. 1956. Population trends in the mountain pine beetle at Windermere Creek, British Columbia. Interim Rept. 1954-6. Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C., 20 pp.

Buffam, P. E. 1965. Establishment report - Wooley Creek mountain pine beetle trend plot, Paisley District, Fremont National Forest. USDA For. Serv., R-6, 11 pp.

Buhyoff, G. J., J. D. Wellman and T. C. Daniel. 1982. Predicting scenic quality for mountain pine beetle and western spruce budworm damaged forest vistas. For. Sci. 28:827-38.

ABSTRACT

The scenic beauty of sixty-four forest vista landscapes, from the Colorado Front Range was measured for a large group of subjects (observers) by the Scenic Beaty Estimation Method. Some of the landscapes evidenced insect-damaged trees and stands. One group of subjects were not told a prioi of the presence of damage; another group was informed. Photo measurements of 91 possible landscape areas as defined by topography, vegetation, and relative viewing distance were made in square inches. Multiple regression models were formulated using the landscape areas as predictors for scenic beauty. Two different regression models resulted: one for uninformed (naive) observers and another for the informed observers. Results indicate that the negative visual impact of insect damage for naive observers is mitigated by the presence of dense forests, long viewing distances, and mountainous terrain. On the other hand, informed observers evaluate insect damage characterized by the red top stage more negatively and the overall scenic beauty measures are lower for damaged stands.

Burnell, D. G. 1977. A dispersal-aggregation model for mountain pine beetle in lodgepole pine stands. Res. Pop. Ecol. 19:99-106.

Cabrera, H. 1978. Phloem structure and development in lodgepole pine. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 54-63.

ABSTRACT

Thickness of phloem and presence of resin canals in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) are important factors in the successful development of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) broods. Thick phloem is closely related to tree vigor, and contains three components: phloem (*Dendroctonus ponderosae* Hopkins) broods. Thick phloem is closely increasement, phloem compression and phloem retention. Individual annual phloem increments make a relatively small contribution to total phloem thickness (usually less than 10%). Compression of old phloem tissue, resulting from increases in tree diameter, reduces the contribution of individual increments to phloem thickness to approximately half their original amount. Retention is the major factor affecting both the ultimate phloem thickness and the rate of change of phloem thickness. For the trees used in this study, the overall average period of phloem retention was 21.7 years, but for individual trees it may be in excess of 40 years in the lower bole. Resin canal density is a highly variable characteristic in lodgepole pine, but overall, densities are

usually higher in the upper parts of the tree. Resin canal density may be a useful indicator of relative tree resistance to bark beetle attack: however, research on other pine species indicates that even short-term environmental stress may result in a substantial temporary reduction in resistance.

Cahill, D. B. 1960. The relationship of diameter to height of attack in lodgepole pine infested by mountain pine beetle. USDA For. Serv. Res. Note INT-78, 4 pp.

Cahill, D. B. 1971. Biological Evaluation. Mountain pine beetle. Black Hills National Forest, Northern Black Hills, Lead and Deadwood Area, South Dakota. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-17, 4 pp.

Cahill, D. B. 1971. Biological Evaluation. Mountain pine beetle. Mount Rushmore National Memorial. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-19, 2 pp.

Cahill, D. B. 1972. Post-control Evaluation. Mountain pine beetle. Black Hills National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-8, 9 pp.

Cahill, D. B. 1972. Biological Evaluation. Mountain pine beetle. Bureau of Land Management, Lander District. USDA For. Serv., Rocky Mtn. Reg., Rept No. R2-72-15, 3 pp.

Cahill, D. B. 1972. Biological Evaluation. Mountain pine beetle. Roosevelt National Forest. USDA For. Serv., Rocky Mtn. Reg. Rept. No. R2-72-16, 3 pp.

Cahill, D. B. 1972. Biological Evaluation. Mountain pine beetle. Pike National Forest, South Platte Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-18, 2 pp.

Cahill, D. B. 1973. Biological Evaluation. Mountain pine beetle. Pike National Forest, South Platte Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-17, 3 pp.

Cahill, D. B. 1973. Biological Evaluation. Mountain pine beetle and dwarf mistletoe, Dillon Reservoir. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-19, 3 pp.

Cahill, D. B. 1973. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-20, 3 pp.

Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Owl Mountain, North Park District, Routt National Forest, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-8, 1 p.

Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Colorado Middle Park, Arapaho and Roosevelt National Forests, BLM, State and Private Lands, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-20, 2 pp.

Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Colorado Front Range, Arapaho and Roosevelt, Pike and San Isabel National Forests, and Rocky Mountain National Park, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-22, 2 pp.

Cahill, D. B. 1975. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, Bureau of Land Management, State and private land, South Pass City-Atlantic City, Wyoming, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-25, 3 pp.

Cahill, D. B. 1976. Biological Evaluation. Mountain pine beetle. Bighorn Front Range, Bighorn National Forest, BLM, State and private land, USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-5, 4 pp.

Cahill, D. B. 1977. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming, Black Hills National Forest and surrounding Federal, state and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-5, 3 pp.

Cahill, D. B. 1978. Cutting strategies as control measure of the mountain pine beetle in lodgepole pine in Colorado. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 188-91.

ABSTRACT

Efforts to suppress mountain pine beetle, (*Dendroctonus ponderosae* Hopkins) epidemics in Colorado have been carried out since the early 1900s using various methods of treating or removing beetle populations. These methods have slowed the rate of annual tree losses, but have done little to reduce total tree mortality over the course of an infestation, or to reduce the susceptibility of the stands to additional beetle attack. Based on recent research findings that demonstrated the importance of lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) phloem thickness and diameter in mountain pine beetle epidemices, stands in the Middle Park area of Colorado were cut using strategies to reduce stand susceptibility to beetle attack. Partial cutting and clearcutting, combined with the logging of infested trees, were used to reduce the inventory of larger-diameter trees. Other factors considered were dwarf mistletoe, comandra rust and visual management concerns. Losses in partial-cut areas have been reduced to 1 to 2 percent of the residual trees, whereas in unmanaged stands 39 percent of the trees have been lost.

Cahill, D. B. and D. W. Johnson. 1976. Biological Evaluation. Rawlins District, Bureau of Land Management, Green Mountains, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-12, 10 pp.

Cahill, D. B. and L. C. Yarger. 1976. Biological Evaluation. Mountain pine beetle - Black Hills of South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-76-3, 3 pp.

* Callaham, R. Z. 1953. Host specificity in the *Dendroctonus* - *Pinus* complex. USDA Bur. Entomol., Berkeley, CA

* Callaham, R. Z. 1953. Studies on the resistance of pines to bark beetle attack. USDA Bur. Entomol., Berkeley, CA

* Callaham, R. Z. 1955. Oleoresin production in the resistance of pines to bark beetle attack. California For. and Range Exp. Sta., Berkeley, CA.

Carey, P. P. and W. R. Wilcox. _____. Disaster to opportunity. Colo. State For. Serv. Leafl.

* Carlson, R. W. 1963. A sampling technique for population studies of the mountain pine beetle. M.S. thesis, Univ. of Michigan, Ann Arbor.

Carlson, R. W. and W. E. Cole. 1965. A technique for sampling populations of the mountain pine beetle. USDA For. Serv., Res. Pap. INT-20, 13 pp.

ABSTRACT

Objectives of this study were: (1) to determine the most satisfactory sample size and sampling location on a tree, and (2) to develop a sampling technique based on optimum size and location of sampling areas. Three variables (besides size and shape of sample unit) in the development of beetle populations were considered: density of attack, length of egg gallery, and brood density at late larval stage.

Carter, S. W., Jr. 1978. Potential impacts of mountain pine beetle and their mitigation in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 27-36.

ABSTRACT

The results of a project to prepare guidelines and prescribe treatment for infested lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stands in the Umatilla and Wallowa-Whitman National Forests in northeastern Oregon are used to illustrate the potential impacts of a mountain pine beetle (*Dendroctonus ponderosae* Hopkins) outbreak on all forest resources. Resources considered are timber, fisheries and wildlife, water, soils, recreation and esthetic value. Guidelines to mitigate the effects on these were developed with respect to the treatment selected, a three-phase harvest program over a 21-year period. This management plan was selected over no action, a two-phase harvest program over a 14-year period, and a two-phase harvest program over a 22-year period as best meeting the over-all management objectives.

Carter, S. W., Jr. 1982. A case study. Impacts of mountain pine beetle and their mitigation in lodgepole pine forests. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv., Rept. BC-X-230, pp. 65-76.

Cerezke, H. F. 1964. The morphology and functions of the reproductive systems of *Dendroctonus monticolae* Hopk. (Coleoptera: Scoloytidae). Can. Entomol. 96:477-500.

ABSTRACT

The male and female reproductive organs of the mountain pine beetle, *Dendroctonus monticolae* Hopk. are described, and interpretations given for functions of the parts on the basis of activity during mating, sperm transfer, egg formation and ovulation. Some morphological changes of the reproductive organs during the adult life cycle are also noted.

Three pairs of accessory glands associated with spermatophore production are evident in the male beetle. One of these was previously termed the seminal vesicles. A complex musculature operates the male genital organ during copulation. The female organs have four telotrophic ovarioles with a posterior calyx region that has a possible secretory function. Evidence indicates that organs previously termed "colleterial glands" have a digestive and reabsorbing function. The bursa copulatrix may be more closely allied with the function of the accessory glands than with the mating process. Parts of the spermatheca have been more precisely defined according to function.

Cerezke, H. F., J. H. Borden and T. N. Trott. 1984. Field tests with semiochemicals for the mountain pine beetle in the Cypress Hills, Alberta. Can. For. Serv. Res. Notes 4:16-8.

Chansler, J. F., D. B. Cahill and R. E. Stevens. 1970. Cacodylic acid field tested for control of mountain pine beetles in ponderosa pine. USDA For. Serv. Res. Note. RM-161, 3 pp.

ABSTRACT

In an operational-scale field test, cacodylic acid (dimethylarsenic acid) was highly effective in preventing brood development of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in ponderosa pines (*Pinus ponderosa* Laws.) that had been infested about 2 weeks before treatment. Beetles infesting trees that had been treated with acid prior to the attack period were also unable to produce brood. Overall treating costs of $2 per tree were substantially lower than other direct-control methods.

Chatelain, M. P., and J. A. Schenk. 1983. Relative abundance, within tree distribution, emergence periods and feeding habits of insect associates of mountain pine beetle in lodgepole pine. Univ. Idaho For., Wildl. and Range Exp. Sta. Res. Note No. 39.

Chatelain, M. P. and J. A. Schenk. 1984. Evaluation of frontalin and exo-brevicomin as kairomones to control mountain pine beetle (Coleoptera: Scolytidae) in lodgepole pine. Env. Entomol. 13:1666-74.

ABSTRACT

Augmentation of entomophagous insects with synthetic attractants for control of mountain pine beetle, *Dendroctonus ponderosae* Hopkins, was evaluated in lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, stands located in central Idaho and northeastern Oregon. The clerid predator, *Thanasimus undatulus* (Say), was the only species that responded to sticky traps baited with either frontalin or exo-brevicomin. Significantly more adults responded to frontalin, and exo-brevicomin was eliminated from subsequent tests. Frontalin was successful in augmenting *T. undatulus* adults on trees baited either before (May-mid-July) or during (mid-July-September) the mountain pine beetle flight period. Baiting before the bark beetle flight period was most effective in augmenting *T. undatulus,* because baiting was concurrent with peak flight activity of the clerid. Frontalin, in association with the host trees, also attracked mountain pine beetle

when used during the latter's flight period. Augmentation of *T. undatulus* adults without aggregating mountain pine beetle was accomplished by removing the attratant before the flight period of the latter. Baiting brood trees in this manner increased the incidence of *T. undatulus* larvae 3-fold, and mortality of emerging mountain pine beetle adults by 7.1%, but did not significantly reduce pine beetle brood survival or consequent tree mortality. However, the influence of the substantially increased predator population may be synergistic with other control tactics, and the use of frontalin should be considered seriously within a pest management program.

Cielsa, W. M. 1971. Evaluation of mountain pine beetle infestations on the Hebgen Lake District, Gallatin National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 71-38, 3 pp.

Ciesla, W. M. 1974 Forest insect damage from high-altitude color-IR photos. Photogram. Eng. 40:683-90.

ABSTRACT

High-altitude color-infrared ERTS-1 underflight photos of a NASA test site in western Montana taken from a U-2 were evaluated for capability to resolve forest insect damage. Three insect outbreaks were known to occur within the test site: a bark beetle, mountain pine beetle *Dendroctonus ponderosae* Hopk.; and two defoliators - pine butterfly *Neophasia menapia* F. and F., and western spruce budworm *Choristoneura occidentalis* Free. Defoliation of ponderosa pine forests by pine butterfly was readily discernible on color IR positive transparencies. Detection of mountain pine beetle damage was only partially successful. Defoliation of current year's foliage by western spruce budworm was not resolved.

Ciesla, W. M. 1978. The mountain pine beetle/lodgepole pine pest management system: Opportunities for putting new knowledge into practice. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 209-12.

ABSTRACT

Opportunities for putting new information on the management of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann)

forests into practice are explored. These are addressed from the viewpoint of what is currently known about insect/host interrelationships, alternative pest management strategies and how they can be integrated with resource management objectives, economics and environmental constraints. In addition, an accelerated program of knowledge utilization efforts, including informal workshops, demonstration of mathematical models and greater involvement of potential users of this technology, is recommended for the final year of this research and development program.

Ciesla, W. M., R. A. Allison and F. P. Weber. 1982. Panoramic aerial photography in forest pest management. Photogram. Eng. 48:719-23.

ABSTRACT

The role of aerial photographs for providing data required in forest pest management is reviewed. The Itek KA-80A optical bar panoramic aerial camera is introduced. Potential applications, advantages, and disadvantages of panoramic photographs in forest pest management are discussed.

Clark, W. R. 1978. Theory and practice of mountain pine beetle management in lodgepole pine forests: A comment. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 208.

Cobb, F. W., Jr., D. L. Wood, R. W. Stark and J. R. Parmeter, Jr. 1968. Theory on the relationships between oxidant injury and bark beetle infestation. Hilgardia 39:141-52.

Cole, D. M. 1973. Estimation of phloem thickness in lodgepole pine. USDA For. Serv., Res. Pap. INT-148, 10 pp.

ABSTRACT

Analysis of data from 288 trees shows that phloem thickness of lodgepole pines is strongly related to tree growth expressions that reflect past tree vigor, such as periodic basal area increment,

and d.b.h. and tree height in conjunction with tree age. Broad habitat-type groupings also significantly influence phloem thickness. Equations presented for estimating phloem thickness of individual trees are usable in construction of phloem thickness distributions for lodgepole pine stands. Such distributions can aid in developing risk classifications for assessing vulnerability of lodgepole pine stands to mountain pine beetle attack.

Cole, D. M. 1978. Feasibility of silvicultural practices for reducing losses to the mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc. For. Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 140-7.

ABSTRACT

A variety of standard silvicultural practices, and variations of them, have been proposed for reducing the losses caused by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) forests. This paper outlines silvicultural practices deemed applicable for a variety of lodgepole pine stand descriptions and management situations: it also discusses factors that limit application and some consequences of misapplication. The necessity that silvicultural practices be compatible with the requirements of forest growth regulation and with management for other resource values is stressed, and an example is given of the role of silvicultural practices in an integrated long-range program for reducing losses.

Cole, D. M. 1985. Effects of outbreaks in relation to host occurrence and resource concerns: occurrence of lodgepole pine stands according to habitat type and successional role. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 31-7.

Cole, D. M. 1985. Coordinating management objectives with silvicultural systems and practices: Acceptable silvicultural systems in relation to desired stand character and successional roles of lodgepole pine. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 45-6.

Cole, D. M. 1985. Silvicultural practices for lodgepole pine stands in commercial forests. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 47-56.

Cole, W. E. 1962. The effects of intra-specific competition within mountain pine beetle broods under laboratory conditions. USDA For. Serv. Res. Note 97, 4 pp.

* Cole, W. E. 1962. Population dynamics of the mountain pine beetle in lodgepole pine. A study plan. USDA For. Serv., Int. Sta., Ogden, UT.

* Cole, W. E. 1963. The mountain pine beetle in lodgepole pine (*Dendroctonus monticolae* Hopk.) (Coleoptera: Scolytidae). A problem analysis. USDA For. Serv., Int. Sta., Ogden, UT

* Cole, W. E. 1963. Population dynamics of the mountain pine beetle in lodgepole pine. Progress Report 1961-1962. USDA For. Serv., Int. Sta., Ogden, UT.

Cole, W. E. 1964. The mountain pine beetle in lodgepole pine (*Dendroctonus monticolae* Hopk.) (Coleoptera: Scolytidae). Study Plan I. Development of sampling procedures. USDA For. Serv., Int. Sta., Ogden, UT.

* Cole, W. E. 1964. The mountain pine beetle in lodgepole pine (*Dendroctonus monticolae* Hopk.) (Coleoptera: Scolytidae). Study Plan II. Studies of populations. USDA For. Serv., Int. Sta., Ogden, UT.

Cole, W. E. 1967. Sampling biologically in forest insect populations. Ann. Entomol. Soc. Am. 60:860-1.

Cole, W. E. 1970. The statistical and biological implications of sampling units for mountain pine beetle populations in lodgepole pine. Res. Popul. Ecol. 12:243-8.

Cole, W. E. 1973. Crowding effects among single-age larvae of the mountain pine beetle, *Dendroctonus ponderosa* (Coleoptera: Scolytidae). Env. Entomol. 2:285-93.

ABSTRACT

An experiment was conducted to determine the effect of crowding on: larval and adult survival; larval stadia duration; sex ratio of adults; reproductive capacity of adult female *Dendroctonus ponderosae* Hopkins.

To investigate distribution of the effect of crowding within a single age group, newly hatched larvae were used. The responses of these larvae and subsequent adults were observed after exposure to densities of 1, 3, 6, and 9 larvae (or adults) per unit of food supply for each of 3 time intervals.

Survival of 1st-stage larvae increased as crowding increased. Survival at the adult stage increased in Crowd 3, decreased in Crowd 9, and was not consistent in Crowd 6 as crowding duration lengthened. The rate of survival decreased as either crowding level increased or duration of crowding lengthened. Crowding influenced the rate of larval development, which in turn influenced sex ratio; i.e., as the 3rd and 4th larval stadia became shorter, more females and fewer males survived. Thus, the theoretical ratio of 1:1 shifted in favor of the female. The reproductive capacity of the female adult decreased as larval crowding increased. There was an apparent feeding stimulus through association that resulted in greater than 60% successful establishment of 1st-stage larvae when crowded.

Cole, W. E. 1973. Interaction between mountain pine beetle and dynamics of lodgepole pine stands. USDA For. Serv. Res. Note INT-170, 6 pp.

ABSTRACT

The influence of habitat types, diameter classes, and phloem thickness on beetle populations and the reverse, the influence of beetle populations on stand dynamics, form a coordinated interrelationship within the lodgepole pine ecosystem. The loss of trees to mountain pine beetles is partly a function of stand structure. Beetle population survival may be dependent upon either food supply or elevation, according to the particular habitat involved. This type of information can be used to estimate the probability of tree loss, risk of infestation, and brood survival.

Cole, W. E. 1974. Competing risks analysis in mountain pine beetle dynamics. Res. Popul. Eco. 15:183-92.

Cole, W. E. 1975. Interpreting some mortality factor interactions within mountain pine beetle broods. Env. Entomol. 4:97-102.

ABSTRACT

The mix of mortality factors within *Dendroctonus ponderosae* Hopkins populations was analyzed by using crude and general probabilities of death from specific causes and from all causes, within specified life stages and for the generation as a whole. These analyses provide the basis for discussion of actual results and some hypothetical cases. Control efforts should accentuate one or more of the controllable causes of mortality or, perhaps eliminate one or more causes, if those remaining would be accentuated. The effect on total mortality of such action may depend heavily on the nature of the interactions among the causes. Knowledge of how mortality factors operate single and particularly in mix will permit additional characterization of the population dynamics of the mountain pine beetle.

Cole, W. E. 1976. Mathematical models for the mountain pine beetle - lodgepole pine interaction. Proceedings, XVI IUFRO World Congress, Norway, 454-6.

Cole, W. E. 1978. Management strategies for preventing mountain pine beetle epidemics in lodgepole pine stands: Based on empirical models. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgpeole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 87-97.

ABSTRACT

Empirical models have been prepared describing the interaction between mountain pine beetle (*Dendroctonus ponderosae* Hopkins) and lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann). These models show the relationship between losses of lodgepole pine and survival of mountain pine beetle by life stages. Further, they identify stand characteristics conducive to mountain pine beetle epidemics and provide the basis for determining probabilities of infestation and resultant tree losses. This probability of infestation and tree loss can be determined for stands of varying diameter/phloem structure and can be further refined as additional information is gained. Harvesting techniques based on this probability can be applied strategically to prevent mountain pine beetle epidemics.

Cole, W. E. 1981. Some risks and causes of mortality in mountain pine beetle populations: a long-term analysis. Res. Popul. Ecol. 23:116-44.

Cole, W. E. and G. D. Amman. 1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. USDA For. Serv. Res. Note INT-95, 7 pp.

ABSTRACT

Tree losses resulting from infestation by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) were measured in two stands of lodgepole pine (*Pinus contorta* Dougl.) where the beetle population had previously been epidemic. Measurement data showed that larger diameter trees were infested and killed first. Tree losses ranged from 1 percent of trees 4 inches (d.b.h.) to 87 percent of those 16 inches and greater d.b.h. Numbers of adult beetle emergence holes averaged 1.3 per square foot of bark area in trees 7 inches d.b.h. and 62 in trees 18 inches and greater d.b.h. The observations indicate that large infestations of mountain pine beetle depend on the presence of large diameter trees within a stand of lodgepole pine, thus implying that beetle population growth is food-limited.

Cole, W. E. and G. D. Amman. 1980. Mountain pine beetle dynamics in lodgepole pine forests. Part I. Course of an infestation. USDA For. Serv. Gen. Tech. Rept. INT-89, 56 pp.

ABSTRACT

Much of this work is original research by the authors. However, published literature on the mountain pine beetle is reviewed with particular reference to epidemic infestations in lodgepole pine forests. The mountain pine beetle and lodgepole pine have evolved into an intensive and highly compatible relationship. Consequently, stand dynamics of lodgepole pine is a primary factor in the development of beetle epidemics. The diameter-growth relationship and the effects of environmental factors on the beetle population provide the basis for assessing potential tree losses and some forest management alternatives to be used. Stand susceptibility and acceptable risks are considered in the use of these management alternatives in order to achieve management's goals.

Cole, W. E., G. D. Amman, and C. E. Jensen. 1976. Mathematical models for the pine beetle - lodgepole pine interaction. Env. Entomol. 5:11-9.

ABSTRACT

Mathematical models describing losses of lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) and survival of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) by life stage were prepared from data covering a 13-yr period. The greatest survival and emergence of beetles/unit area of bark occurred in trees of large diameter. After most trees of large diam. were killed, gallery starts and egg production continued to increase. However, larval survival declined and emergence returned to the endemic level. At high densities of gallery starts and inches, beetle survival was low, probably because of excessive competition among larvae and drying of phloem. Under these conditions of stress, the sex ratio appears to shift further in favor of ♀ after most of the large trees are killed. These observations demonstrate the close association of beetle dynamics with diam. structure of lodgepole pine stands, and support the theory that epidemics are strongly dependent upon the presence of large trees having thick phloem.

Cole, W. E., G. D. Amman and C. E. Jensen. 1985. Mountain pine beetle dynamics in lodgepole pine forests Part III: Sampling and modeling of mountain pine beetle populations. USDA For. Serv. Gen. Tech. Rept. INT-188, 46 pp.

Cole, W. E. and D. B. Cahill. 1976. Cutting strategies can reduce probabilities of mountain pine beetle epidemics in lodgepole pine. J. For. 74:294-7.

ABSTRACT

Mountain pine beetle attacks in lodgepole pine stands are generally concentrated on trees of large diameter and thick phloem, and brood production is greatest within such trees. Three lodgepole stands infested at various epidemic levels were sampled in 1971 and pre-epidemic diameter and phloem thickness distributions were estimated. Estimates of residual food supplies for beetles when partial cutting levels were applied to the data show that managing the stands so that trees did not reach 10 inches dbh would have substantially lowered the probabilities that epidemics would develop.

Cole, W. E., D. B. Cahill, and G. D. Lessard. 1983. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine: Preliminary evaluation, East Long Creek Demonstration Area, Shoshone National Forest, Wyoming. USDA For. Serv. Res. Note INT-333, 11 pp.

ABSTRACT

Diameter-limit and leave-tree cuts were tested as ways to reduce or minimize lodgepole pine losses to the mountain pine beetle. In the first year after treatment, loss reductions were proportional to the intensity of cut. According to the Rate of Loss Model, the 100-leave-tree cut was the best deterrent of recurring infestation, measured as amount of losses and length of time. The 100-leave-tree cut also should provide the best regeneration and has the added benefit of reducing dwarf mistletoe infection.

Cole, W. E., E. P. Guyman, and C. E. Jensen. 1981. Monoterpenes of lodgepole pine phloem as related to mountain pine beetles. USDA For. Serv. Res. Paper INT-281, 10 pp.

Cole, W. E. and R. J. Klade. 1975. Black beetles and green trees. USDA For. Serv., Intermountain For. & Range Exp. Sta., 5 pp.

Cole, W. E. and M. D. McGregor. 1983. Reducing or preventing mountain pine beetle outbreaks in lodgepole pine stands by selective cutting. In L. Safranyik (ed.). The role of the host in the population dynamics of forest insects. Proc. IUFRO Conf., Banff, Alberta, Can., pp. 175-85.


ABSTRACT

Selective cuts based on dbh and phloem thickness reduced lodgepole pine losses to the mountain pine beetle. Loss reductions were proportional to the intensity of cut. According to the Rate of Loss Model, the 100-leave-tree cut was the best deterrent of recurring infestation, measured in terms of total mortality and length of time of the infestation. The 100-leave-tree cut also should provide the best regeneration and has the added benefit of reducing dwarf mistletoe infection.


Cole, W. E. and M. D. McGregor. 1983. Estimating the rate and amount of tree loss from mountain pine beetle infestations. USDA For. Serv. Res. paper INT-318, 22 pp.


ABSTRACT

Because of recurrent depredations by the mountain pine beetle in lodgepole pine, managers have less than a 50-percent chance of growing lodgepole pine to 16-inch diameters in most stands. This paper describes a Rate of Loss Model that estimates the amount of tree and volume loss per year and the longevity of the infestation, and shows how the model can be incorporated into forest planning. The model assumes optimum conditions for the life of an epidemic. However, actual field conditions can cause beetle populations to deviate from predictions causing a bit of overestimation, which is not considered serious in most infestation cases.

The model predictions, based on 2-inch diameter classes as populations, are further modified by habitat type. The classification provides the framework essential for organizing information to select alternative management activites for habitat types. The Rate of Loss Model has been integrated with the Insect and Disease Damage Survey (INDIDS) models to estimate mortality trends for stands with ongoing mortality or to obtain loss estimates by diameter class over infestation time for green stands, should they become infested.

One approach to modeling tree mortality caused by the mountain pine beetle uses FORPLAN to predict susceptible areas within analysis areas, which one would be affected, and the expected mortality over two decades. Or, when stands within analysis areas are identified through timber or stand exam surveys, beetle attack may then be simulated by a "prescription" that shows the effects of an epidemic in the absence of timber management.

The model has been verified using some 2,500 stands in the Forest Service's Northern Region. By using assessments from FORPLAN and harvesting in high hazard, susceptible stands before an epidemic develops, land managers should be able to minimize tree mortality caused by the beetle.

Cole, W. E. and R. F. Shepherd. 1967. The mountain pine beetle *Dendroctonus ponderosae* Hopk., In A. G. Davidson and R. M. Prentice (Eds.). Important forest insects and diseases of mutual concern to Canada, the United States and Mexico. Can. Dept. For. Rural Dev. Publ. 1180, pp. 13-15.

Cole, W. E. and C. Weenig. 1967. A technique for inducing attacks and mating of the mountain pine beetle, *Dendroctonus ponderosae* ( = *monticolae)* (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 60:857-8.

Collis, D. G. and N. E. Alexander. 1966. Mountain pine beetle damage to western white pine on Vancouver Island. Can. Dept. For., For. Res. Lab., Victoria, B.C. Inf. Rept. BC-X-9, 5 pp.

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Cook, J. A . 1959. Induced drought on lodgepole pine (*Pinus contorta* var. *latifolia* Engl.) and its relationship to successful mountain pine beetle (*Dendroctonus monticolae* Hopk.) attacks. For. Biol. Lab., Calgary, Alberta, 8 pp.

Conn, J. E., J. H. Borden, B. E. Scott, L. M. Friskie, H. D. Pierce, Jr., and A. C. Oehlschlager. 1983. Semio-chemicals for the mountain pine beetle, *Dendroctonus ponderosae,* in British Columbia: field trapping studies. Can. J. For. Res. 13:320-4.

ABSTRACT

The following compounds were field tested in multiple funnel or drainpipe traps as attractants for the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in British Columbia lodgepole pine, *Pinus contorta* var. *latifolia* Engelm. forests; *trans*-verbenol, 3-caren-10-ol, acetophenone, E-2-methyl-6-methylene-octa-2.7-dienol (myrcenol) and 2-p-menthen-7-ol (all female-produced volatiles which had proven attractive in laboratory bioassays): *exo*-brevicomin (produced by males); and a-pinene, B-pinene, 3-carene, B-phellandrene, terpinolene and myrcene (host tree monoterpenes), *trans*-verbenol was demonstrated to be a highly active aggregation pheromone, as was (+)-*exo*-brevicomin. Myrcene was the most effective synergistic monoterpene, while a-pinene was completely ineffective. In one experiment, 3-caren-10-ol caused a shift in favor of responding males, but the other female-produced volatiles were inactive.

Coulson, R. N., G. D. Amman, D. L. Dahlsten, C. J. DeMars, Jr., and F. M. Stephen. 1985. Forest-bark beetle interactions: Bark beetle population dynamics. In W. E. Waters, R. W. Stark and D. Wood (eds.). Integrated pest management in pine-bark beetle ecosystems. John Wiley & Sons, Inc., pp. 61-80.

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Cox, R. G. 1972. Progress Report No. 8. Cooperative research on control of the mountain pine beetle in western white pine. Bark Beetle Committee, Montana-Northern Idaho For. Pest Action Council, Lewiston, ID, 28 pp.

ABSTRACT

This report reviewed and condenses results of seven years of cooperative "mission oriented" research to attempt to develop new methods of suppressing the mountain pine beetle *(Dendroctonus ponderosae)* in white pine *(Pinus monticolae)* in northern Idaho.

Forest tests in 1971 strongly demonstrated that the synthetic chemical messenger pondelure (a mixture of 9 parts *trans*-verbenol and 1 part *alpha*-pine) deployed on sticky traps significantly reduced mortality of white pine caused by the mountain pine beetle. A cost-benefit analysis showed the control effort to be justified. Thus pondelure becomes an important adjunct to the biological control of bark beetles in a way which is beneficial to the forest environment. Other 1971 tests assessed (1) additional pheromone candidate compounds, (2) alternate techniques and media for deploying the attractant, (3) the use of systemic chemicals injected into baited trees as a means of inhibiting beetle broods, and (4) the use of large-scale color aerial photographs to identify white pines killed by bark beetles.

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ABSTRACT

Has control work against bark beetles paid? Approximately one million dollars have been expended on a number of control projects. This article is a discussion of the economics of control work and is a candid appraisal of what the money has bought in the way of values saved and of experience gained for guiding future control efforts. With bark beetles still important factors, the recommendations for control policies here offered are particularly timely.

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Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Bighorn National Forest and adjacent BLM, State and private lands, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-6, 3 pp.

Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Salida and San Carlos Ranger Districts, Pike and San Isabel National Forests, Colorado. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-7, 3 pp.

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Creasap, V. L. M. 1977. Biological Evaluation. Mountain pine beetle. Colorado Front Range, Arapaho and Roosevelt, Pike and San Isabel National Forests and adjacent lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-77-13, 6 pp.

Creasap, V. L. M. 1978. Biological Evaluation. Mountain pine beetle. Bighorn National Forest and adjacent BLM, State and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept No. R2-78-1, 4 pp.

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## ABSTRACT

Silvicultural planning requires reliable estimates of stand growth, species and tree size composition, and mortality levels. Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infestations are inherent events in the development of many lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stands. Therefore, tree mortality expected from future infestations must be considered when planning for the use of stands which may sustain appreciable beetle-caused mortality. The mountain pine beetle population dynamics simulation program (MPBMOD) has been coupled to prognosis model for stand development (TREMOD). Together these models form a unified program (TREINS1) which can be used by forest managers and research workers to explore management alternatives designed to reduce beetle-caused losses of lodgepole pine. This paper describes how the information produced by TREINS1 can be used by timber managers. The program design, limitations, data requirements and operation are discussed.

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## ABSTRACT

The locations of mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), infestations in lodgepole pine (*Pinus contorta* Dougl.) forests between 1945 and 1975 are mapped. The intervals between infestations at selected locations from 1910 to 1975 were tabulated and found to vary between 6 and 64 years.

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## ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae,* and 68 associated insect species were reared from infested sugar pine, *Pinus lambertiana*. Portions of three infested trees were sectioned by height and the insects emerging from each were identified and recorded. In one tree the number of woodpecker strikes also was noted. The tops of two of the three trees were infested by another bark beetle, *Pityophthorus confertus,* and from these same two trees the most common parasite obtained was *Macromesus americanus*.

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ABSTRACT

This paper is a summary of the studies during 1930, 1931, and 1932 in the white pine stands of eastern Washington and northern Idaho, of the biology and habits of *Dendroctonus monticolae* Hopk. Previous studies have never fully accounted for the rapid increase

in the number of infested trees during outbreaks, nor have they adequately explained increases which have occurred subsequent to control work in several instances. Factual knowledge along such lines is essential to the efficient planning and execution of future control projects.

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ABSTRACT

The potential of high altitude panoramic photography for improving the efficiency of statewide mountain pine beetle *(Dendroctonus ponderosae* Hopkins) damage surveys in ponderosa pine *(Pinus ponderosa* Laws.) forests is discussed.

Based on the successful results of an earlier design test, a pilot test of the new inventory procedure was conducted over 5.5 million acres in teh Front Range of Colorado. The results compared favorably with those from a conventional survey conducted concurrently.

Use of Itek KA-80A optical bar panoramic photography in a loss assessment survey is an alternative to the conventional survey technique. The new survey procedure has a potential for increased survey efficiency, while providing total photographic coverage of the target area. The photographic coverage can serve as a resource data base for other applications.

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ABSTRACT

It is a well recognized fact that insects exert a powerful influence on the development and structure of a forest. Although many beneficial effects accrue from their activites, the changes which they bring about are frequently at odds with the desires of man. Losses of mature trees caused by insects are usually keenly realized because they deplete resources of present economic value; but less direct losses, which may occur concurrently in stands of low present value, frequently pass unnoticed.

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ABSTRACT

This paper gives a brief history of the destruction of standing timber resulting from an epidemic of the mountain pine beetle (*Dendroctonus monticolae* Hopk.) in the lodgepole pine stands of the Beaverhead National Forest, Mont. During the past decade the outbreak has swept through this area of 1,341,860

acres, killing approximately 57,756,000 trees above 3 inches in diameter. The total loss of merchantable trees 9 inches d.b.h. and above is estimated to be 77.3 percent.

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ABSTRACT

A simple generic model for the dispersion of pheromones in a forested ecosystem is presented. Methods for the calculation of various concentration related parameters are described. The influence of different micrometeorological conditions on concentration profiles is discussed. Two separate studies from two different geographical locations lend support to the predictions of the dispersion model. For two different species of *Dendroctonus* beetles, aggregation behavior was correlated with meteorological condition resulting from inversion profiles.

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Freeling, A. N. S. and D. A. Seaver. 1980. Decision analysis in Forest Service planning: treatment of the mountain pine beetle. Decision Science Consortium, Inc., Tech. Rept. 80-8, 93 pp.

Frye, R. H. 1974. Biological Evaluation. Mountain pine beetle. Pike and San Isabel National Forest, Salida Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-74-8, 2 pp.

Frye, R. H. 1974. Biological Evaluation. Black Hills National Forest and adjacent State and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-74-12, 4 pp.

Frye, R. H. 1975. Biological Evaluation. Mountain pine beetle. Pike and San Isabel and Arapaho National Forests. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-1, 5 pp.

Frye, R. H. and T. D. Landis. 1975. Mountain pine beetle and dwarf mistletoe, Lake Creek Area, San Carlos Ranger District, Pike and San Isabel National Forests. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-75-4, 10 pp.

Fuchs, M. G. and J. H. Borden. 1985. Pre-emergence insecticide applications for control of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). J. Entomol. Soc. Brit. Columbia 82:25-28.

ABSTRACT

An experiment was set up near Princeton, British Columbia to investigate the efficacy of carbaryl (Sevin SL) and chlorpyrifos and (Dursban 4E) at 1% and 2% a.i. in water, to prevent the successful emergence of mountain pine beetles, *Dendroctonus ponderosae* Hopkins, from infested lodgepole pines, *Pinus contorta* var. *latifolia* Engelmann. All treatments were effective in killing the emerging beetles outright. Mortality ranged from 83.3% for 1% Sevin to 94.9% for 2% Dursban, compared with 6.1% mortality of beetles emerging from water-treated control trees. Living emergent beetles from all treatments suffered >50 and >90% mortality after 1 and 5 days, respectively, compared with 5 and 10 days, respectively, for beetles from control treatments.

Fuller, L. R. 1983. Incidence of root diseases and dwarf mistletoe in mountain pine beetle killed ponderosa pine in the Colorado Front Range. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-83-2, 8 pp.

* Furniss, R. L. 1941. Memorandom on examination of the 1940-41 pine beetle control project on the Wasatch National Forest -- June and July 1941. USDA Bur. Entomol., Portland, OR

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Furniss, R. L. and V. M. Carolin. 1977. Western forest insects. USDA For. Serv., Misc. Pub. No. 1339.

Furniss, M. M. and J. A. Schenk. 1969. Sustained natural infestation by the mountain pine beetle in seven new *Pinus* and *Picea* hosts. J. Econ. Entomol. 62:518-9.

ABSTRACT

During 1965-1967, mountain pine beetles infested 143 exotic conifer trees in the Shattuck Arboretum at the University of Idaho. One hundred trees (70%) were killed. Ranked in order of numbers of trees attacked, the tree species were: *Pinus sylvestris, P. strobus, P. resinosa, P. banksiana, P. nigra, P. rigida* and *Picea abies*. The trees were 24 to 51 years old. Beetles killed a higher proportion (78%) of attacked *P. strobus*, a higher rate of success than in other tree species. In *P. strobus*, egg galleries averaged 6.6/ft$^2$ and from which 91 progeny emerged per sq. ft. High susceptibility of *P. strobus* to beetles should be considered by geneticists seeking to hybridize *P. strobus* with *P. monticola* for the former's greater resistance to white pine blister rust.

Gara, R. I., D. R. Geiszler, and W. R. Littke. 1984. Primary attraction of the mountain pine beetle to lodgepole pine in Oregon. Ann. Entomol. Soc. Am. 77:333-4.

ABSTRACT

Dispersing *Dendroctonus ponderosae* landed preferentially on lodgepole pines with fire scars and decay ($P$ = 0.023 and $P$ = 0.008, respectively, by joint binomial distribution analysis).

Gara, R. I., W. R. Littke, J. K. Agee, D. R. Geiszler, J. D. Stuart and C. H. Driver. 1985. Influence of fires, fungi and mountain pine beetles on development of a lodgepole pine forest in south-central Oregon. In D. M. Baumgartner, R. G. Krebill, J. T. Arnott and G. F. Weetman (eds.). Lodgepole pine - the species and its management. Symp. Proc., Coop. Ext., Wash. State Univ., pp. 153-62.

ABSTRACT

Virtually pure lodgepole pine stands form an edaphic climax community over large areas of the infertile "pumice plateau" of south-central Oregon. During our ongoing studies on the dynamics of these forests we developed the scenario that periodic fires create fungal infection courts in damaged roots; in time, advanced decay develops in the butts and stems of these trees. The mountain pine beetle preferentially selects and kills these trees during the flight season. As these outbreaks develop, additional uninfected trees are attacked. In time, the stage is set for subsequent fires as needles drop, snags fall, and logs decay.

* Geiszler, D. R. 1979. Mountain pine beetle attack dynamics on lodgepole pine. M. S. thesis, Univ. of Washington, Seattle, 92 pp.

Geiszler, D. R. and R. I. Gara. 1978. Mountain pine beetle attack dynamics in lodgepole pine. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 182-7.

ABSTRACT

The "switching mechanism" by which mountain pine beetles (*Dendroctonus ponderosae* Hopkins) will kill lodgepole pine *(Pinus*

*contorta* Douglas var. *murrayana* (Greville and Balfour) Engelmann) in groups during outbreaks was investigated. The agents causing beetles to switch from attacking a "focus" tree to attacking a "recipient" tree appear to be the sequential effects of aggregative and anti-aggregative pheromones. Analysis of the attack rates shows that recipient trees are initially attacked more quickly than trees baited with *trans*-verbenol and $\alpha$-pinene. Regression analysis shows that beetles select recipient trees on the basis of tree diameter and distance from the focus tree. Thinning prescriptions based on a tolerance interval about a regression line relating diameters of recipient trees to distance from the focus tree might be used to reduce beetle kill.

Geiszler, D. R., V. F. Gallucci, and R. E. Gara. 1980. Modeling the dynamics of mountain pine beetle aggregation in a lodgepole pine stand. Oecologia 46:244-53.

ABSTRACT

At least once a year the mountain pine beetle searches for lodgepole pines that provide a suitable habitat for a new brood. After attacking females feed, they produce an attractant pheromone that causes beetles to aggregate and, during outbreaks, to usually mass attack the "focus" tree. Near the completion of mass attack, incoming beetles are repelled and initiate attacks on adjacent "recipient" trees. An understanding of this "switching" process is useful for prescribing measures that minimize beetle damage.

A mathematical model was developed to (1) describe beetle aggregation, (2) predict the relation of tree susceptibility and switching to changes in beetle density, (3) provide a structure for current knowledge, and (4) pose questions for further research. The model indicates that a high population density ensures mass aggregation and consequently successful tree colonization and switching. The model also indicates that the number of beetles attracted per attacking beetle differs from tree to tree, possibly depending on resin quality and production and/or the local flying density of beetles. Field and model results indicate that tree size appears to affect the repellence of beetles, suggesting that the attack density or the visual attractiveness of large trees is a factor. Further research could be directed at our assumptions on host resistance, repellence, pheromone emission rates, threshold concentrations, navigation, and pheromone dispersion.

Germain, C. J. and N. D. Wygant. 1967. A cylindrical screen cage for rearing bark beetles. USDA For. Serv. Res. Note RM-87, 4 pp.

ABSTRACT

Describes a 4-legged cage 12 inches in diameter and 24 inches high, made from 20-mesh wire screen and a tractor funnel. A mason jar fits over funnel outlet to collect the emerging beetles.

* Gibson, A. L. 1926. Progress report of study of epidemics of *Dendroctonus monticolae* in lodgepole pine and yellow pine. Bitterroot National Forest. 1925. USDA Bur. Entomol., Coeur d' Alene, ID

* Gibson, A. L. 1927. The lodgepole pine-mountain pine beetle study. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1927. Parthenogenesis of *Dendroctonus monticolae* Hopk. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1928. Investigations of mountain pine beetle in lodgepole pine. Progress Report No. 2. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1928. Investigations of mountain pine beetle in lodgepole pine and yellow pine. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1928. Some results of investigations of the mountain pine beetle in relation to lodgepole pine and yellow pine. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1929. Investigations concerning the mountain pine beetle in lodgepole pine. Progress Report No. 3. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1930. Investigations concerning the mountain pine beetle in lodgepole pine. Progress Report No. 4. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1931. The mountain pine beetle in western white pine, 1930 progress report. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1933. Testing repellents and control measures for the mountain pine beetle and studying certain phases of its life history in lodgepole pine. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1935. Status of the mountain pine beetle infestation in ponderosa pine stands on the Bitterroot National Forest. 1934. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1936. Spraying with lethal oil to control the mountain pine beetle in lodgepole pine. USDA Bur. Entomol., Coeur d'Alene, ID

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* Gibson, A. L. 1937. Study of a mountain pine beetle infestation in lodgepole pine. USDA Bur. Entomol., Coeur d'Alene, ID

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* Gibson, A. L. 1939. Progress report - spraying with penetrating oils to control the mountain pine beetle in lodgepole pine. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1940. Spraying with various penetrating oils in the search for a better method of controlling the mountain pine beetle in lodgepole pine 1939. USDA Bur. Entomol., Coeur d'Alene, ID

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* Gibson, A. L. 1940. Wasatch experimental control project. Supp. Rep. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1941. Experiments with penetrating sprays conducted in lodgepole and white bark pine in 1940. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1941. Tests to determine repellent and control effectiveness of certain formulae of the Dow Chemical Company 1940. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1942. Tests with penetrating sprays against the mountain pine beetle in lodgepole and whitebark pine 1940-41. Grand Teton National Park. USDA Bur. Entomol., Coeur d'Alene, ID

Gibson, A. L. 1943. Penetrating sprays to control the mountain pine beetle. J. Econ. Entomol. 36:396-8.

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* Gibson, A. L. 1943. Spring control of the mountain pine beetle in western white pine with penetrating sprays, 1942. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson. A. L. 1943. Status and effect of a mountain pine beetle infestation on lodgepole pine stands. USDA Bur. Entomol., Coeur d'Alene. ID. 34 pp.

* Gibson, A. L. 1944. Fall control with penetrating sprays against the mountain pine beetle in western white pine, 1943. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1946. Control of the mountain pine beetle in western white pine with DDT, 1944-45. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1951. An instance of winter mortality of broods of the mountain pine beetle, 1949-50. USDA Bur. Entomol., Coeur d'Alene, ID

* Gibson, A. L. 1952. Tests of penetrating sprays to control bark beetles, 1951--Mountain pine beetle in lodgepole and western white pine. USDA Bur. Entomol., Coeur d'Alene, ID

Gibson, K. E. 1977. Results of a pilot study to test the efficacy of three insecticides in preventing attacks by the mountain pine beetle in lodgepole pine. USDA For. Serv., Ogden, UT, 8 pp.

ABSTRACT

A pilot study was undertaken to test the efficacy of three Insecticides: Lindane, Sevin and Dursban in preventing attacks by the mountain pine beetle in lodgepole pine. Methods used in the selection, plot design and chemical application are described. Results indicating success or failure of the insecticides used are included.

Gibson, K. E. 1978. Results of a 1977 pilot project to evaluate the effectiveness of Sevin insecticide in preventing attacks by the mountain pine beetle in lodgepole pine on the Targhee National Forest, Idaho. USDA For. Serv., Intermountain Reg., Rept No. R-4 78-4, 22 pp.

Gibson, K. E. 1978. Damage assessment of a mountain pine beetle infestation, Targhee National Forest, Idaho. USDA For. Serv., Intermountain Reg. Rept. No. R-4 78-7, 5 pp.

ABSTRACT

Trend studies conducted on the Targhee National Forest, Idaho, indicate that in one stand, during the past five years, 86 trees per acre have been killed by the mountain pine beetle. This represents 69.5 percent of the stand 6 inches dbh and larger. These data could affect management decisions for similar stands of lodgepole pine.

Gibson, K. E. 1981. Permanent mountain pine beetle population trend plots: an update, 1981. USDA For. Serv., Northern Reg., Rept. 81-14, 4 pp.

Gibson, K. E. 1982. Permanent mountain pine beetle population trend plots: an update, 1982. USDA For. Serv., Northern Reg., Rept. 82-19, 5 pp.

Gibson, K. E. 1982. Management alternatives for lodgepole pine recreational facilities threatened by the mountain pine beetle. USDA For. Serv., Northern Reg., Rept. No. 82-27, 3 pp.

Gibson, K. E. 1983. Permanent mountain pine beetle population trend plots: an update, 1983. USDA For. Serv., Northern Reg., Rept. 83-17, 6 pp.

ABSTRACT

For the fourth year since their establishment, the six permanent plot locations in Montana were revisited following beetle flight in 1982. Beetle populations remained low in five of the six areas. Only in the Murr Creek plots did newly attacked trees represent an epidemic beetle population. In the Centennial Valley location, several plots had been logged. Growth and phloem thickness data were collected from Murr Creek, Boulder Creek, and Dunsire Creek in an effort to explain why beetle numbers are not building in these areas as rapidly as we had anticipated. Insufficient data has been collected, as yet, to reach meaningful conclusions.

Gibson, K. E., and D. Bennett. 1979. Overwintering survival of mountain pine beetle larvae and resultant effects on beetle populations in the Northern Region in 1979. USDA For. Serv., Northern Reg. Rept. No. 79-15, 10 pp.

ABSTRACT

During December 1978 and January 1979, temperatures reached all-time lows in some parts of Montana. Overwintering mountain pine beetle populations were sampled at 11 sites during February and March 1979. Effects of the extreme cold varied from site to site, with larval mortality ranging from 6 percent to 100 percent. As a result, beetle populations will likely be reduced substantially in some areas and affected little in others.

Gibson, K. E., M. D. McGregor and G. D. Amman. 1985. Demonstration of the effectiveness of basal area cutting to reduce tree killing by the mountain pine beetle in ponderosa pine, Crow and Northern Cheyenne Indian Reservations, Montana, 1984: Establishment report. USDA For. Serv., Northern Reg., Rept. 85-8, 9 pp.

ABSTRACT

During 1984, a demonstration project was established on the Crow and Northern Cheyenne Indian Reservations to determine the effectiveness of basal area cutting in second-growth ponderosa pine stands to reduce losses to the mountain pine beetle. This project will help develop management strategies for susceptible stands in eastern Montana. Four treatments, replicated twice on each Reservation, will be implemented: reduction of existing basal area through partial-cutting to 50, 65, and 80 square feet/acre and no-cutting (control). After treatment, each block will be monitored yearly for the first 5 years, then at 5-year intervals for 20 years.

Gibson, K. E., M. D. McGregor, and D. D. Bennett. 1980. Establishment Report: Permanent mountain pine beetle trend plots, Montana, 1979. USDA For. Serv., Northern Reg., Rept. 80-8, 17 pp.

Gibson, K. E., M. D. McGregor and J. E. Dewey. 1980. Evaluation of a mountain pine beetle infestation in second growth ponderosa pine on the Crow Indian Reservation, Montana, 1979. USDA For. Serv., Northern Reg., Rept. No. 80-2, 11 pp.

ABSTRACT

The mountain pine beetle infestation in Corral, Little Corral, and Cache Creeks on the Crow Indian Reservation, Montana has been increasing for the past several years. Trees killed per acre averaged 38.8 in 1979. Our predictions for the future trend of the infestation, plus management alternatives to lessen its severity, are outlined in this report.

Gibson, K. E., M. D. McGregor and R. D. Oakes. 1985. Mountain pine beetle infestation in ponderosa pine on Crow/Northern Cheyenne Indian Reservations, Montana, 1984. USDA For. Serv., Northern Reg., Rept. No. 85-9, 16 pp.

ABSTRACT

The mountain pine beetle infestation existing on the Crow Indian Reservation (IR) since the early 1970's, and later developing principally in the western portion of the Northern Cheyenne IR, continued into 1984. Survey results indicate the infestation is still building on both Reservations. To help develop beetle management strategies appropriate for stands in eastern Montana, studies to demonstrate the effects of several partial-cut regimes have been initiated. That project and currently held management philosophies for mountain pine beetle in second-growth ponderosa pine are discussed.

Gosnell, R. et al. 1980. The Front Range Vegetation Management Pilot Project: The "we" commitment. Colo. St. For. Serv., Colo. St. Univ., Ft. Collins, CO.

* Graves, H. S. 1897-98. 19th Ann. Rept. U. S. Geol. Survey, Pt. 5, p. 87.

Gray, B., R. F. Billings, R. I. Gara and R. L. Johnsey. 1972. On the emergence and initial flight behaviour of the mountain pine beetle, *Dendroctonus ponderosae,* in Eastern Washington. Z. angew Entomol. 71:250-9.

ABSTRACT

Emergence from ponderosa pine and initial flight behaviour of the bark beetle, *Dendroctonus ponderosae* were studied under field conditions. Hourly emergence increased as ambient temperatures rose from 20 to 30°C but deline markedly about 30°C. Essentially no emergence activity occurred on days when temperatures remained below 16°C. Under optimal temperature conditions (23-30°C), peak hourly emergence did not synchronize with maximum daily temperatures, suggesting that emergence is controlled rhythmically. The average sex ratio of emergent adults was 1 male to 1.4 females, although diurnal variation was considerable. In flight tests, newly emergent adults generally flew with the wind in the absence of pheromones. In contrast, in the presence of synthetic *trans*-verbenol and fresh host material, most male and female beetles flew directly towards the attraction source against the wind. Flight exercise was not a prerequisite to olfactory response. Flight height above the ground appeared to be independent of either ambient temperature or wind speed. Although the proportion of beetles which responded to attractants decreased with increasing wind speeds, several beetles flew against winds exceeding 7.5 km/h.

Griffin, D. N. 1975. Thinning a ponderosa pine stand to reduce mountain pine beetle caused mortality on the Ninemile District, Lolo National Forest. M.S. Thesis, Wash. St. Univ., Pullman, 46 pp.

ABSTRACT

A mountain pine beetle outbreak near Missoula, Montana killed an estimated 100,000 ponderosa pine trees from 1969 to 1971. A sanitation low thinning was installed in 1971 to find out if thinning even-aged, second-growth, mixed ponderosa pine and Douglas-fir stands would reduce beetle killed trees. The results of the five year study are discussed for a control unit and a thinned unit. In general, groups of trees are killed and tree mortality varies directly with basal area per acre. The variable plot data show that the diameter and height of the dead trees are almost identical with the average diameter and height of all pine trees in each basal area category. However, more small diameter trees are killed than larger diameter trees when the plot data are averaged for the entire stand. Thinning the Issac Creek stand appears to have drastically reduced beetle kill but thinning might have reduced the stand's volume growth more than the beetle has reduced stand growth. This paper briefly reviews the literature on thinning ponderosa pine stands to prevent mountain pine beetle attack and the effect thinning has on the growth of ponderosa pine stands.

Hall, P. M. and T. F. Maher. 1986. Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, 158 pp.

* Hall, R. C. 1953. An improved appraisal survey method for bark beetle damage in ponderosa and Jeffrey pine in the California Region. Calif. For. and Range Exp. Sta., Berkeley, CA

Hall, R. C. 1964. Results of thinning ponderosa pine in reducing insect-caused losses, Joseph Creek Basin, Modoc National Forest. USDA For. Serv., Div. Timber Mgmt, San Francisco, CA, 13 pp.

ABSTRACT

This report describs the three years' results of an administrative thinning study undertaken in the Joseph Creek Basin of the Modoc National Forest in a very dense stand of ponderosa pine poles about 70 years old which had suffered serious depletion due, primarily, to the attacks of

the mountain pine beetle. The initial thinning was done in the winter of 1960-61. An additional thinning was carried out in the late winter of 1962 and proceeded throughout 1963. The purpose of the study was to determine if thinning, through the reduction in competition, would result in reducing insect-caused losses in the residual stand. Davies [1] reported on this administrative study with a rather detailed description of the area, objective, procedures, and results for the first season.

Hall, R. C. and G. R. Davies. 1968. Mountain pine beetle epidemic at Joseph Creek Basin, Modoc National Forest. USDA For. Serv., Div. Timber Mgmt., San Francisco, CA, 22 pp.

ABSTRACT

This report summarizes the information gained from the studies and surveys made of the Joseph Creek Basin mountain pine beetle epidemic. The infestation, present in the stand for at least 13 years and epidemic for the last six of those years, subsided when precommercial thinning was completed. The primary source of information for this report is the thinning study begun in the winter of 1960-61.

Hall, R. C. and J. R. Pierce. 1965. Sanitation treatment for insect control. USDA For. Serv., Div. Timber Mgmt. Report, R-5, 21 pp.

Hamel, D. R. 1977. Status of mountain pine beetle infestations in second-growth ponderosa pine stands, Little Rocky Mountains, Fort Belknap Reservation, Montana, 1977. USDA For. Serv., Northern Reg., Rept No. 77-18, 6 pp.

ABSTRACT

Mountain pine beetle infestations in second-growth ponderosa pine developed in 1973 in the Little Rocky Mountains. In 1976, increasing numbers of attacked trees were observed. Current infestation intensity averages 7.1 trees per acre. Losses are expected to continue as long as stands remain overstocked and stagnated. Reduction of basal area by commercial sales and/or thinning is recommended. Precautions are given to prevent population buildup of secondary bark beetles.

Hamel, D. R. 1978. Results of harvesting strategies for management of mountain pine beetle infestations in lodgepole pine on the Gallatin National Forest, Montana. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 192-6.

ABSTRACT

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) epidemics in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) are correlated with large diameter, thick-phloemed trees, and decline of epidemics is associated with loss of these trees. Beetle brood production is directly correlated with phloem thickness, which is directly related to tree diameter. Probabilities of mountain pine beetle-caused losses to lodgepole pine can be developed from phloem thickness/tree diameter distribution data. Based on these probabilities, harvesting strategies were implemented in 1974 on the Gallatin National Forest to reduce average tree diameter and assess the effect on population build-up. Harvesting of four 16-ha (40-acre) blocks within heavily infested areas, based on diameter and phloem distributions, was completed in 1976. A 3-year post-harvest evaluation will determine the efficacy of this management alternative. Preliminary results indicate beetle population reductions in blocks harvested to 25- and 30-cm (10- and 12-inch) diameter limits, but population build-up in the block harvested to an 18-cm (7-inch) limit and in the block harvested on the basis of phloem thickness. Population build-ups were also noted in check blocks.

Hamel, D. R., G. D. Amman, M. D. McGregor, W. E. Cole, and L. A. Rasmussen. 1975. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Montana. USDA For. Serv., Northern Reg., Establishment Rept. No. 75-12, 11 pp.

Hamel, D. R. and M. D. McGregor. 1976. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Montana. USDA For. Serv., Northern Reg., Rept. No. 76-3, 7 pp.

Hamel, D. R. and M. D. McGregor. 1976. Evaluation of mountain pine beetle infestations; Lap, Cool, Lang, and Caribou drainages, Yaak Ranger District, Kootenai National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 76-6, 10 pp.

ABSTRACT

Mountain pine beetle reached epidemic levels in the Lap, Cool, Lang, and Caribou Creek drainages in 1974. From 1973 to 1975, approximately 56,282 trees with an estimated volume of 4,365,660 board feet were killed in these areas. An additional 61,721 trees are predicted to be killed in 1976. Currently infested acreage on the Yaak Ranger District equals 5,110 ac. (2,068 ha). This represents 5% of the 118,345 ac. (47,894 ha) risk rated high and given Priority 1 for management treatment. Selective logging to remove infested and susceptible trees is recommended to reduce the epidemic trend.

Hamel, D. R. and M. D. McGregor. 1976. Biological notes on the emergence of mountain pine beetle and associates from lodgepole pine, Gallatin National Forest, Montana, 1975. USDA For. Serv., Northern Reg., Rept. No. 76-7, 7 pp.

ABSTRACT

Emerged beetles were first collected July 17 and peak emergence occurred between August 10 and 26, 1975. Density of attacks averaged four per 0.5 ft.$^2$ (0.05m$^2$). Parent to brood ratio was 1:4.6. Thirteen associate insects, representing six families of Coleoptera and one of Diptera, were recovered. Associates included predators and secondary bark beetles. Future studies dependent on mountain pine beetle emergence require initiation or completion prior to mid-July.

Hamel, D. R., M. D. McGregor, and M. J. Berg. 1975. Status of mountain pine beetle infestations, Yellowstone National Park, Wyoming, 1973. USDA For. Serv., Northern Reg., Rept. No. 75-4, 7 pp.

ABSTRACT

The mountain pine beetle infestation has been epidemic in lodgepole pine in Yellowstone National Park since 1966. Infestation boundaries have advanced steadily northward and eastward. The infestation now encompasses nearly one-half of the total Park area. Surveys indicate a decline in tree mortality the last 2 years. In 1970, an average of 18.9 lodgepole pine was killed per acre. In 1971, 19.0 were killed per acre. In 1972 and 1973, these figures declined to 16.7 and 6.6 trees per acre respectively. Average diameter of attacked trees has decreased from 12.0 inches d.b.h. in 1971 to 10.0 inches d.b.h. in 1973. A decrease in number of infested trees occurred in order infestation centers in the southwest corner of the Park due to depletion of available hosts.

Hamel, D. R., M. D. McGregor, and M. J. Berg. 1975. Status of mountain pine beetle infestations, Yellowstone National Park, Wyoming, 1974. USDA For. Serv., Northern Region, Rept. No. 75-6, 6 pp.

ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae* Hopk., infestation in Yellowstone National Park advanced north and eastward in 1974. New infestation centers were located along the east shore of Yellowstone Lake and south of the Promontory to the Park's southern boundary. Ground surveys indicated an average of 2.9 infested trees per acre. Average diameter of attacked trees was 11.0 inches. A decrease in number of infested trees continues to occur in older portions of the infestation in the southwestern corner of the Park. The outbreak has been declining since 1971 and the 1974 survey indicates a continued decline.

Hamel, D. R., M. D. McGregor, R. C. Lood, and H. E. Meyer. 1975. Evaluation of mountain pine beetle infestations, Snell Creek and Warland Peak Areas. Fisher River District, Kootenai National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 75-21, 9 pp.

ABSTRACT

Mountain pine beetle infestations in the Snell Creek and Warland Peak areas were evaluated in October 1975. Based on current buildup ratios, tree diameter distributions, stand composition and phloem thicknesses, there appears to be limited opportunity for epidemic potential in either area. Management alternatives are discussed. Selective logging is recommended to further decrease epidemic potential and reduce the infestations to endemic status.

Hamel, D. R., M. D. McGregor, and R. D. Oakes. 1977. Harvesting strategies for management of mountain pine beetle infestations in lodgepole pine, Gallatin National Forest, Montana. Progress Report - 1976. USDA For. Serv., Northern Reg., Rept. No. 77-6, 7 pp.

Hamel, D. R., M. D. McGregor, and R. D. Oakes. 1977. Evaluation of a mountain pine beetle infestation, Jack Creek Drainage, Madison District, Beaverhead National Forest, Montana, 1976. USDA For. Serv., Northern Reg., Rept. No. 77-9, 8 pp.

ABSTRACT

Mountain pine beetle populations developed to epidemic level in lodgepole pine stands in 1973. Approximately 426,355 trees were killed on 3,433 hectares in 1976. Infestations are expected to intensify in areas of current infestation and develop in uninfested stands. It is predicted that 1,722,288 trees will be killed in 1977. Salvage logging of infested trees and silvicultural management to reduce average stand diameter below 20.3 cm d.b.h. are recommended.

Hamel, D. R. and R. D. Oakes. 1977. Evaluation of mountain pine beetle infestation Lap, Cool, and Caribou Drainages, Yaak District, Kootenai National Forest. 1976. USDA For. Serv., Northern Reg., Rept. No. 77-8 7 pp.

ABSTRACT

Mountain pine beetle infestations developed to epidemic level in lodgepole pine stands on the Yaak District in 1972. Approximately 56,282 trees were killed from 1973 to 1975. By 1975, 2,068 ha were infested. This increased to 7,138 ha in 1976, representing a three-fold increase. Current infestation occurs on 13 percent of the area risk rated high and given Priority 1 rating for management. Selective logging to remove infested and susceptible trees is in progress and it is recommended that these practices continue to reduce the infestation to endemic levels.

Hamel, D. R. and R. D. Oakes. 1977. Evaluation of a mountain pine beetle infestation, Gold Creek Drainage, Rexford District, Kootenai National Forest, Montana. 1976. USDA For. Serv., Northern Reg., Rept. No. 77-10, 8 pp.

ABSTRACT

A mountain pine beetle infestation developed in lodgepole pine stands in the Gold Creek drainage in 1974. From 1974 to 1976 approximately 19,000 trees with an estimated volume of 10,210 cu m were killed. Based on buildup ratios, stand structure, size of trees, and residual green stand, it is predicted that 5,756 trees will be killed in 1977. Three management alternatives are discussed and selective logging is recommended.

Hamel, D. R. and R. D. Oakes. 1977. Status of mountain pine beetle infestations in second-growth ponderosa pine stands, Little Belt and Big Snowy Mountains, Lewis and Clark National Forest, Montana. 1976. USDA For. Serv., Northern Reg., Rept. No. 77-14, 6 pp.

ABSTRACT

Mountain pine beetle infestations in second-growth ponderosa pine have been chronic in the Little Belt and Big Snowy Mountains since 1947. In 1976, increasing numbers of attacked trees were observed. Current infestation intensity averages 82 trees per hectare. Losses are expected to continue as long as stands remain stagnated. Commercial sales and thinning to reduce basal area below 34 $m^2$/ha* are recommended. Precautions are given to prevent population buildup of secondary bark beetles.

Hamel, D. R., R. D. Oakes, and R. Hothem. 1977. Potential for infestation by mountain pine beetle in lodgepole pine stands, Hungry Horse District, Flathead National Forest, 1977. USDA For. Serv., Northern Reg., Rept. No. 77-11, 6 pp.

ABSTRACT

Ground surveys on the Hungry Horse District indicate a potential for mountain pine beetle infestation in lodgepole pine. Based on elevation-latitude, mean d.b.h. and phloem thickness, and age, stands were given a susceptibility classification of high risk. An infestation in Glacier National Park may provide the beetle source. Management alternatives are discussed and long-term management goals are recommended.

Hamilton, D. B., J. E. Roelle and W. B. White. 1985. Mountain pine beetle damage and contagion modeling: some concepts and approaches. USDA For. Serv., Methods Appl. Group Rept. No. 85-6, 25 pp.

ABSTRACT

This paper describes various concepts and approaches relative to modeling mountain pine beetle (MPB) contagion effects within and among forest stands for use as a component of Integrated Pest Impact Assessment System (IPIAS). This information was developed at a workshop held June 25-29, 1984, in Breckenridge, Colorado (Hamilton et al. 1984)[3/]. The workshop participants focused on two critical aspects: 1) a mountain pine beetle damage model, and 2) the dynamics of a contagion model.

In developing a mountain pine beetle damage model, participants avoided the usual population dynamics approach. The advantage of not

having an explicit representation of mountain pine beetle numbers is the avoidance of many nonquantified relationships that would otherwise be required. The primary calculations in the mountain pine beetle model will include: 1) hazard indices based on stand characteristics; 2) trees killed; 3) an MPB brood production index; 4) the probability of an outbreak starting or growing; and 5) an updated MPB index based on current year brood production and dispersal.

The contagion model will calculate how the beetles, and related tree mortality, will spread to surrounding stands. Several different approaches to representing this phenomenon were discussed. A modification of a dispersal matrix (grid cell) approach previously used to model dispersal of spruce budworm was proposed as a starting point.

The results of this workshop will come to fruition through an Intra-Agency Agreement (IAG-RM-84-73) "Development of Pest, Stand and Contagion Models and Integration Into a Geographic Information System", with Intermountain Forest and Range Experiment Station; Principal Investigator, Albert R. Stage.

Haneman, Deirdre M. 1983. Mountain pine beetle, Shirley Mountains, Wyoming-1982. USDA For. Serv., Rocky Mtn. Reg., Bio Eval. R2-83-3, 12 pp.

Haraden, R. C. 1982. United States National Park Service management policies and their relationship to mountain pine beetle pest management programs. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USDA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 54-57.

Harris, J. W. E., A. F. Dawson and R. G. Brown. 1981. Evaluation of mountain pine beetle damage using aerial photography taken with a hand-held 70-mm camera, Gold Bridge - Clinton, B. C., 1981. Env. Can., Can. For. Serv., Pac. For. Res. Cent., Info Rept. BC-X-245.

Harris, J. W. E., A. F. Dawson, and R. G. Brown. 1982. Evaluation of mountain pine beetle damage using aerial photography, Flathead River, B. C., 1980. Env. Can., Can. For. Serv., Pacif. For. Res. Cent., BC-X-228, 10 pp.

ABSTRACT

A low-budget multistage sampling procedure was applied in 1980 to a 14,750-ha area in the Flathead River Valley in southeastern British Columbia. Lodgepole pine (*Pinus contorta)* stands with trees killed by mountain pine beetle, *Dendroctonus ponderosae,* were sketch-mapped during aerial surveys. Twenty-six 1-ha airphoto plots at a scale of 1:5,000 were established on a grid pattern, using Kodak MS Aerochrome 2448 true color transparency film, together with a subsample of nine 0.25-ha ground subplots.

Ground-to-airphoto dead-tree count ratios were calculated for the nine subplots and beetle-killed pine were counted on the 26 photo plots. The "ground-corrected average number of dead trees per hectare" was determined for the 26 photo plots by multiplying the average number of trees killed per hectare on the 26 photo plots by the average of the nine subplot ratios. The number of killed trees was then estimated for the total area. A height-diameter curve was constructed from ground subplot data to calculate an average tree volume, which was applied to the total estimated number of killed trees to estimate the total volume loss for the area.

In the affected area, an estimated 5.3 million trees had been killed since 1976, mostly from 1979 attack. Volume losses were over 1.3 million cubic meters.

Sampling error was 18.5% for tree counts and 38.9% for volume. Ninety-three per cent of the volume loss occurred in trees were dbh of 15 cm or larger. Study costs were about 85 cents per hectare. An improved sampling design based on this experience is described. It would use 1:6,000 70-mm color photography with sketch-mapping. 4-ha airphoto plots and 0.25-ha photo-ground subplots.

Harvey, R. D., Jr. 1979. Rate of increase of blue stained volume in mountain pine beetle killed lodgepole pine in northeastern Oregon, USA. Can. J. For. Res. 9:323-6.

ABSTRACT

Recently killed lodgepole pine *(Pinus contorta* Dougl.) were examined to determine rate of spread of blue stain fungi introduced by mountain pine beetle *(Dendroctonus ponderosae* Hopk.). Trees were felled, dissected at 2.5 m intervals, and photographed at each cross section to determine area of stain. Rate of spread is so rapid that salvaging mountain pine beetle killed lodgepole pine prior to severe staining is difficult.

Harvey, R. D., Jr. 1986. Deterioration of mountain pine beetle-killed lodgepole pine in Northeast Oregon. USDA For. Serv., Pac. N.W. Reg. Rept. R6-86-13, 9 pp.

ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae* Hopkins, is a periodic forest pest in most mature lodgepole pine (*Pinus contorta* Dougl. ex Loud) stands. Outbreaks develop in lodgepole pine stands after the trees reach 80 to 100 years of age. Mountain pine beetle outbreaks typically start in large-diameter trees because they provide the food and lviing space necessary for brood develoment. Outbreaks continue until the large-diameter component of the stand is killed; the average diameter of the living residual is usually below 8 inches DBH (Safranyik 1974). Trees smaller than 4 inches in diameter are attacked only occasionally.

Stands in the Blue Mountain outbreak area became established in the 1860's following fires that destroyed the former stands. Losses to mountain pine beetle were estimated to be in excess of 116 million board feet in this area between 1972 and 1974.

The rate of deterioration of beetle-killed lodgepole pine is an important consideration in developing salvage and fire management plans. This information was lacking when the outbreak erupted. Consequently, an evaluation that could provide some of this information was designed and initiated in 1975. The evaluation area included portions of the Wallowa-Whitman and Umatilla National Forests.

Hawksworth, F. G., C. K. Lister, and D. B. Cahill. 1983. Phloem thickness in lodgepole pine: its relationship to dwarf mistletoe and mountain pine beetle (Coleoptera: Scolytidae). Env. Entomol. 12:1447-8.

ABSTRACT

A generally accepted hypothesis is that lodgepole pines infected by dwarf mistletoe *Arceuthobium americanum*, are less susceptible to mountain pine beetle, *Dendroctonus ponderosae*, because they have thinner phloem than uninfected trees. This Colorado study based on 1,051 trees, indicates that there is little relationship between dwarf mistletoe intensity and phloem thickness. Therefore, we conclude that there is little correlation between dwarf mistletoe and mountain pine beetle activity, at least in Colorado.

Hay, C. J. 1956. Experimental crossing of mountain pine beetle with Black Hills beetle. Ann. Entomol. Soc. Am. 49:567-71.

Heinricks, J. 1983. The lodgepole killer. J. For. 81:289-92.

Heller, R. C., J. L. Bean and F. B. Knight. 1959. Aerial surveys of Black Hills beetle infestations. USDA For. Serv., Rocky Mtn. For. and Range Exp. Sta. Paper No. 46, 8 pp.

* Hensill, G. S. 1936. Some olfactory responses of the mountain pine beetle (*Dendroctonus monticolae* Hopk.). USDA Bur. Entomol., For. Insect Lab, Berkeley, CA

Hester, D. A. 1939. Instructions for surveys and control of bark beetle outbreaks in the Central Rocky Mountain Region. USDA Bur. Entomol. and Plant Quar., Fort Collins, CO, 19 pp.

Higby, P. K. and M. W. Stock. 1982. Genetic relationships between two sibling species of bark beetles (Coleoptera: Scolytidae), Jeffrey pine beetle and mountain pine beetle, in northern California. Ann. Entomol. Soc. Am. 75:668-74.

ABSTRACT

The genetic relationship between two sibling bark beetle species from northern California, the Jeffrey pine beetle, *Dendroctonus jeffreyi* Hopkins, and the mountain pine beetle, *D. ponderosae* Hopkins, was examined by electrophoresis. The genetic differences found between the Jeffrey pine beetle and the mountain pine beetle support their current designation as separate species. Two gene loci were fixed for different alleles in the two groups and provide strong evidence that gene flow does not occur between them. At several other loci, less striking but nevertheless significant differences were observed. The level of overall genetic similarity between the Jeffrey pine beetle and the mountain pine beetle was much lower than that found between conspecific populations of either group.

Hinds, T. E., L. R. Fuller, E. D. Lessard, and D. W. Johnson. 1984. Mountain pine beetle infestation and Armillaria root disease of ponderosa pine in the Black Hills of South Dakota. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-30, 7 pp.

ABSTRACT

A total of 115 trees were examined on 40 plots located throughout the northern Black Hills National Forest. A significant association (P = 0.05) was found between *Armillaria mellea* root disease and ponderosa pine tree mortality attributed to mountain pine beetle infestation. Seventy-five percent of the dead trees, 28% of the currently beetle-infested trees, but none of the live trees had *A. mellea* root infection. All trees had good crown ratios and were equally distributed between single- and two-storied stands of moderate basal area on good quality sites.

* Hoffman, C. H. 1948. Mountain pine beetle control aerial dispersion of DDT. Agr. Res. Cnter., Beltsville, MD.

Homestake Mining Company. 1963. Black Hills beetle - Grim foe of Rocky Mountain pines. Share Bits 14(8):2-23.

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Hopkins, A. D. 1902. Insect enemies of the pine in the Black Hills Forest Reserve. USDA Div. Entomol. Bull. 32, 24 pp.

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Hopkins, A. D. 1910. Some insects injurious to forests. USDA Bur. Entomol., Bull. No. 58, 114 pp.

Hopkins, A. D. 1912. Insect damage to standing timber in the National Parks. USDA Bur. Entomol., Circ. No. 143, 10 pp.

* Hopkins, A. D. 1921. Contributions toward a monograph of the scolytid beetles. I. The genus *Dendroctonus*. II. Preliminary classification of the superfamily scolytidae. USDA Bur. Entomol., Tech. Series 17, 247 pp.

* Hopping, G. R. 1921. The control of bark-beetle outbreaks in British Columbia. Can. Dept. Agr., Entomol. Gr., Cir. 15.

Hopping, G. R. 1946. Control of the more injurious bark beetles of the Canadian Rocky Mountain Region. Can. Dept. Agr., Div. Ent. Proc. Pub. 49.

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Hopping, G. R. 1951. Forest entomology in relation to silviculture in Canada. Part V. The mountain pine beetles. For. Chron. 27:26-9.

Hopping, G. R. and G. Beall. 1948. The relation of diameter of lodgepole pine to incidence of attack by the bark beetle, *Dendroctonus monticolae* Hopkins. For. Chron. 24:141-5.

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Hostetler, B. B. 1978. Biological Evaluation. Mountain pine beetle. Black Hills National Forest and adjacent Federal, State and private lands of South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-3, 5 pp.

Hostetler, B. B. and R. W. Young. 1979. A pilot survey to measure annual mortality of ponderosa pine caused by the mountain pine beetle in the Black Hills of South Dakota and Wyoming. 1977. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-15, 20 pp.

Hostetler, Bruce B. and Robert W. Young. 1979. Estimation procedures for determining annual tree mortality caused by the mountain pine beetle. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-20, 25 pp.

ABSTRACT

Multistage sampling techniques were used in 1978 to estimate ponderosa pine mortality caused by the mountain pine beetle in the Black Hills of South Dakota and Wyoming. Using aerial sketch mapping information, the survey area of 651,000 acres (263,000 ha) was stratified into 3 intensity classes based on the estimated number of dead trees per acre. Each of the 2 highest intensity classes or strata were sampled from large scale (1:6,000) color aerial photographs and on the ground. Samples were selected using systematic random procedures in the first stage and probabilities proportional to size in the second stage.

Correlations between photo and ground counts were very good for each stratum sampled. On the 303,000 acres sampled, an estimated 318,000 ponderosa pine representing a volume of 5,629,000 cubic feet were killed in 1978. These number and volume estimates had standard errors of 4.2 and 7.2 percent, respectively.

Hughes, P. R. 1973. Effect of alpha-pinene exposure on *trans*-verbenol synthesis in *Dendroctonus ponderosae* Hopk. Die Naturwissenschaften 60:261-2.

Hughes, P. R. 1973. *Dendroctonus:* Production of pheromones and related compounds in response to host monoterpenes. Z. Ang. 73:294-312.

ABSTRACT

Bark beetles in the genus *Dendroctonus* produce a number of volatile compounds upon contact with host oleoresin during the initial periods of attack. These compounds, not found in the host and apparently oxidation products of the monoterpene fraction, were also produced when the beetles were exposed to individual monoterpene vapors or when terpenes were applied topically. A linear relationship was noted in female *D. brevicomis* between the period of exposure to alpha-pinene and the production of the terpene alcohol *trans*-verbenol. Removal of the antennae or maxillary and labial palpi which are major centers of chemoreception failed to alter this relationship. Detection of these various oxidation products in the hemolymph of *D. ponderosae* and *D. valens* after exposure to certain monoterpenes established that ingestion

of terpenes is not necessary to their production and that the metabolism occurs outside of the alimentary canal. The character of these metabolic products suggested that a non-specific mechanism of oxidation of cyclic compounds at the allylic carbons is common in *Dendroctonus*. In addition, the production of a six carbon alcohol on exposure to alpha-pinene suggests that cleavage of the terpene molecule may occur in some cases. *Exo*-brevicomin in female *D. brevicomis* was found to decline significantly after mating.

These studies provided the basis for a working hypothesis on the origin and mechanism of synthesis of one class of scolytid aggregating pheromones. Furthermore, techniques are presented which may help in the future isolation and identification of these pheromones.

Hunt, D. W. A., J. H. Borden, J. E. Rahe and H. S. Whitney. 1984. Nutrient-mediated germination of *Beauveria bassiana* Conidia on the integument of the bark beetle *Dendroctonus ponderosae* (Coleoptera: Scolytidae). J. Invert. Path. 44:304-14.

ABSTRACT

Field-collected adult mountain pine beetles, *Dendroctonus ponderosae,* were inoculated with the white muscardine fungus, *Beauveria bassiana,* and thoroughly examined externally with a scanning electron microscope. Germinating conidia were found at a very low incidence, and only on antennal clubs. However, mortality of inoculated controls was high, and *B. bassiana* was confirmed as the causative agent. Germination on the cuticle was greatly increased by sonication of adult beetles. The hypothesis that hemolymph released through sonication-damaged membranes provided a nutrient stimulus that enhanced conidial germination was tested by placing hemolymph or yeast-malt extract broth on the cuticle of otherwise nontreated beetles, which were then inoculated with conidia. Significant germination occurred on the cuticle of these beetles. Therefore, a limiting factor for conidial germination on the sclerotized cuticle of *D. ponderosae* is probably a lack of sufficient nutrients.

Hynun, B. G. and A. A. Berryman. 1980. *Dendroctonus ponderosae* (Coleoptera: Scolytidae): preaggregation landing and gallery initiation on lodgepole pine. Can. Entomol. 112:185-91.

ABSTRACT

Landing rates as monitored by landing traps indicate that the mountain pine beetle, *Dendrocotnus ponderosae* Hopkins, is not

attracted to lodgepole pine, *Pinus contorta* Dougl., prior to the first gallery start. Bark terpene odors and DBH were not correlated with beetle landing rates, with the exception of beta-phellandrene which accounted for a statistically significant 18% of the variation in landing rates. Beetles were unable to distinguish between hosts, dead hosts and nonhosts during landing. The elderberry pith bioassay indicated the presence of a gallery initiation stimulant in the bark.

Hynun, B. G. and A. A. Berryman. 1981. *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae): Gallery initiation on lodgepole pine during aggregation. Env. Entomol. 10:842-6.

ABSTRACT

Gallery starts by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, were observed during aggregation on lodgepole pine, *Pinus contorta* Dougl. Two phases of gallery initiation were identified: acceleration and deceleration. The acceleration phase is characterized by an increasing rate of gallery initiation and was highly variable in the trees sampled. The deceleration phase is characterized by a decreasing rate of gallery initiation and was significantly and linearly correlated with cumulative gallery starts a day or more old (r = -0.24). Transformation of the data to adjust for variation between trees increased the correlation between the deceleration rate and cumulative gallery starts a day or more old to -0.97. The resulting improvement in correlation suggests that variation in mountain pine beetle attack rates between trees can be attributed primarily to host factors. A linear model of gallery initiation during aggregation is presented.

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Johnson, D. W., L. C. Yarger, D. C. Minnemeyer and V. E. Pace. 1976. Dwarf mistletoe as a predisposing factor for mountain pine beetle attack of ponderosa pine in the Colorado Front Range. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-4, 7 pp.

* Johnson, J. W. 1942. The composition of insect infestations in ponderosa and jeffrey pines, Lassen National Forest, seasons of 1940 and 1941. USDA Bur. Entomol, Berkeley, CA.

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Johnson, P. C. 1949. Determining bark beetle hazard of pine stands in northeastern California. J. For. 47:277-84.

ABSTRACT

The proportion of trees and volume in trees recently killed by bark beetles, and the proportion of live trees now classified as highly susceptible to beetle attack may be used as indices of beetle hazard in northeastern California pine lands. These same indices afford a basis for determining control measures and estimating their cost.

* Johnson, P. C. 1951. Height of broods as a factor affecting the treatment of standing lodgepole pine trees infested by the mountain pine beetle. USDA Bur. Entomol., Coeur d'Alene, ID.

Johnson, P. C. 1972. Bark beetle risk in mature ponderosa pine forests in western Montana. USDA For. Serv. Res. Paper. INT-119, 32 pp.

ABSTRACT

The Ponderosa Pine Risk Rating System developed in California was studied in western Montana to determine whether it could effectively identify individual mature trees most frequently killed by the western pine beetle, *Dendroctonus brevicomis* LeConte, or the mountain pine beetle, *D. pondeorsae* Hopkins (Coleoptera: Scolytidae).

Risk 3 and Risk 4 trees--the high risk trees of the four-rating system--comprised 20 percent of the board-foot volume of 12,000 merchantable, risk rated ponderosa pine trees at 35 localities. On study plots in 22 of these localities, ponderosa pine stands that remained undisturbed throughout the study intially contained 17 percent of their total pine volume in Risk 3 and Risk 4 trees. Risk 3 and Risk 4 trees, however, made up 76 percent of the volume of all ponderosa pine trees killed by populations of the two pine beetles on these plots during the study.

Ponderosa pine mortality from the two pine beetle species was consistently low during the study, amounting to a mean of only 15.5 board feet per acre per year on the 22 undisturbed study plots--an amount considerably less than the estimated gross ponderosa pine increment on the same plots.

Subsidiary information obtained from the study indicated that (1) external crown characteristics used by the risk rating system in California to delineate the risk of mature ponderosa pine trees to attack by the western pine beetle were equally effective for this purpose in western Montana; (2) Risk 3 and Risk 4 ponderosa pine trees, together, grew an average of 0.18 inch radially during one 10-year period of the study, and Risk 1 and Risk 2 pine trees grew an average of 0.43 and 0.31 inch, respectively; (3) in 15 mature ponderosa pine stands where soil characteristics were measured, Risk 3 and Risk 4 trees were progressively more abundant as the fertility, productivity, and water-holding capacity of the soils decline; and (4) the mountain pine beetle was not an important primary killer of mature ponderosa pine trees during the study, and it exerted little influence in predisposing low risk trees to attack by the western pine beetle.

It was concluded from the study that managers of mature ponderosa pine forests in western Montana can use the risk rating system to assess the susceptibility of these forests, or of individual ponderosa pine trees in them, to lethal attacks of the western pine beetle for 10 years or more during periods of endemic beetle populations.

* Johnson, P. C. and R. F. Schmitz. 1965. *Dendroctonus ponderosa* Hopk. (Coleoptera:Scolytidae), a pest of western white and ponderosa pines in the northern Rocky Mountains. Problem Analysis. USDA For. Serv., 4500-FS-INT-2202, 87 pp.

Jones, R. G. and W. G. Brindley. 1970. Tests of 8 rearing media for the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae) from lodgepole pine. Ann. Entomol. Soc. Am. 63:313-6.

ABSTRACT

Eight rearing media were tested for suitability for rearing the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, from lodgpeole pine, *Pinus contorta* Douglas. The 2 media containing cellulose rather than lodgepole phloem were not successful. Two phloem-based media produced adults from 36.7 and 21.4% of the 1st stage larvae applied to them. Development time of the insects, size and condition of the adults, and ability of the adults to produce viable eggs when artificially infested in lodgepole pine log sections were studied.

Wild adults mated on most media. Eggs were laid on 4 phloem-containing media but only 1 proved viable.

Katovich, Steven. A. 1984. A comparison of mountain pine beetle, *Dendroctonus ponderosae* Hopkins, risk rating systems in an endemic situation. Univ. Wyo., M.S. Thesis, 115 pp.

Katovich, S. A. and R. J. Lavigne. 1986. The applicability of available hazard rating systems for mountain pine beetle in lodgepole pine stands of southeastern Wyoming. Can. J. For. Res. 16:222-5.

ABSTRACT

Five hazard rating systems for *Dendroctonus ponderosae* Hopkins in *Pinus contorta* Dougl. stands were compared under nonoutbreak conditions in the Medicine Bow Mountains of southeastern Wyoming. The applicability of these systems, which were designed in other regions of the United States, to *P. contorta* stands in southeastern Wyoming was investigated. Thirty-two stands in four different age and diameter categories were sampled and rated by each system. Diameter at breast height did not correlate well with phloem width in any of the stands, as implied by the system of Amman and co-workers.

A direct phloem width measurement could further refine this system. Periodic growth ratio, used in both the Berryman and Mahoney systems, did not differentiate between fast- and slow-growing trees. Crown competition factor did not positively correlate with increasing diameter at breast height, as implied by the system of Schenk and co-workers. Stand production ranged from 11.1 to 51.0 g wood m leaf area $^{-2}$ year $^{-1}$, applying a modified system based on that designed by Mitchell and co-workers, indicating very high risk in every stand sampled. Further development and validation of hazard rating systems is necessary for improved analysis of risk to *P. contorta* stands from *D. ponderosae* in this region.

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Klein, W. H. 1973. Beetle-killed pine estimates. Photogramm. Eng. 39:385-8.

ABSTRACT

A study was undertaken to determine the feasibility of detecting mountain pine beetle-killed lodgepole pine with 35-mm color aerial photographs at a 1:5,000 scale. Photographs were obtained with a standard 35-mm camera from a light aircraft. Counts of dead trees were made from stereo photographs by untrained

interpreters and compared to actual ground counts. Additionally, interpreters were asked to separate new faders from all other mortality. Both tree condition categories were discerned from the photos with acceptable accuracy, indicating the potential of 35-mm aerial photography as an inexpensive and effective measurement method. The method was to be applied operationally in 1971 within the framework of a double-sampling design.

Klein, W. H. 1973. Evaluating a mountain pine beetle infestation with the aid of 35 mm photography. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 8 pp.

Klein, W. H. 1974. Evaluating a mountain pine beetle infestation with the aid of 35 mm aerial photography - Report No. 2. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 5 pp.

Klein, W. H. 1975. Evaluating a mountain pine beetle infestation with the aid of 35 mm aerial photography - Report No. 3. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 6 pp.

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Klein, W. H. 1976. Preliminary report of a survey to measure the impact of the mountain pine beetle in a lodgepole pine forests. USDA For. Serv., Int. Mtn. Reg., Ogden, UT, 7 pp.

ABSTRACT

During the past two decades, the mountain pine beetle has seriously depleted the lodgepole pine forests of the Intermountain West. Using 35mm color aerial photography, a double sampling system, and permanently established plots, measurements of stand depletion were made in a 120,222 acre management area on the Targhee National Forest, Idaho, in 1972-73. Additional to measurements of standing live and beetle-killed timber, data was also obtained on reproduction, forage yield, habitat type, disease

(mistletoe), and other factors that will yield insight into the effects of mountain pine beetle damage on other forest resources. A remeasurement of all plots in 1975 showed that although there was some additional tree mortality, there was a net increase in both lodgepole and total stand volume. Plans are to remeasure these plots at periodic intervals as a base (model) for predicting future yield.

Klein, W. H. 1978. Strategies and tactics for reducing losses in lodgepole pine to the mountain pine beetle by chemical and mechanical means. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For. Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 148-58.

ABSTRACT

The mountain pine beetle (*Dendroctonus ponderosae* Hopkins), easily the most destructive bark beetle in the West, has ravaged the lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) forests of the northern Rockies since the turn of the century. The progress of mountain pine beetle epidemics in lodgepole pine is traced from a beginning in northern Montana in 1909 to full-scale outbreaks that progressed southward through the lodgepole pine forests of southern Idaho, western Wyoming and northern Utah. During the past two decades, the infestation pattern has reversed itself, with outbreaks recurring in parts of northern Utah, southern Idaho, western Wyoming, and back into Montana. Various control strategies employing a variety of methods, practically all of which entailed treatment of individual trees, were attempted, but at best only a few were touted as successful. The large-scale and costly control programs that were aimed at portions of large outbreaks and undertaken during the late 1950s and early 1960s in the Intermountain area failed to stop the infestations. During the 1970s, emphasis changed from individual tree control to individual tree protection. Methods are available for protecting high-value trees from beetle attacks, but they may be relatively costly and are impractical on a forest-wide basis. Individual tree treatment continues to be a management option, but a poor one. Long-lasting control can best be achieved by application of preventive techniques. In some instances, a do-nothing policy could be a viable alternative.

Klein, W. H. 1979. Measuring damage to lodgepole pine caused by the mountain pine beetle. In: USDA For. Serv. Gen. Tech. Rept. WO-8, pp. 35-42.

Klein, W. H. 1982. Estimating bark beetle-killed lodgepole pine with high altitude panoramic photography. Photo. Eng. & Remote Sensing 48:733-7.

ABSTRACT

Panoramic color IR aerial photography taken from a U-2C was evaluated to determine its effectiveness in quantifying annual mortality of lodgepole pine caused by mountain pine beetle. A multistage survey using probability proportional to size (PPS) at three levels was used to estimate numbers of trees and volume killed.

Mortality of lodgepole pine in 1977 was estimated at 1,891,510 ± 194,804 trees, and 27,001,000 ± 3,682,000 cubic feet of volume. Problems encountered with interpretation and data analysis are discussed. The results suggest that panoramic photography can be effectively used to estimate annual mortality of lodgepole pine caused by mountain pine beetle over large areas.

Klein, W. H., D. D. Bennett and R. W. Young. 1979. A pilot survey to measure annual mortality of lodgepole pine caused by the mountain pine beetle. USDA For. Serv., Methods Application Group, Rept. No. 78-4, 15 pp.

ABSTRACT

A pilot survey utilizing multistage sampling techniques was undertaken on the Targhee National Forest during 1977 to measure annual mortality of lodgepole pine by the mountain pine beetle. The survey area, 397,000 acres, was stratified by aerial sketch-mapping into three intensity classes; each stratum was independently sampled by large scale (1:6000) color aerial photography and ground truth. Additional stand data was taken on randomly selected ground plots.

The correlations between photo and ground counts for each stratum were generally good. Stratification by aerial sketch-mapping reduced the population variance and improved the sampling errors. Mortality estimates of mountain pine beetle-killed lodgepole pine for 1976 were 3,609,627 trees and 64,761,000 cubic feet. Prior to 1976, the standing dead lodgepole pine was estimated at 17,751,000 trees and 249,515,000 cubic feet. The basal area ratio of the residual green stand to total dead was 63%.

Mountain pine beetle damage surveys will be conducted in portions of Montana, South Dakota, and Wyoming in 1978. Methods will be essentially similar to this survey with some modifications.

Klein, W. H., D. D. Bennett and R. W. Young. 1980. Evaluation of panoramic reconnaisance aerial photography for measuring annual mortality of lodgepole pine beetle. USDA For. Serv., Northern Reg., Rept. No. 80-2, 21 pp.

ABSTRACT

High elevation, panoramic infrared photography taken from a U-2 aircraft was evaluated to determine its effectiveness in quantifying annual mortality of lodgepole pine caused by the mountain pine beetle in a 520,640-acre outbreak in portions of the Beaverhead and Gallatin National Forests in Montana. A multistage, variable probability design using probability proportional to size (PPS) at three levels was used throughout the survey.

The results suggest that panoramic photography can be effectively used to provide precise estimates of mountain pine beetle-caused annual mortality of lodgepole pine over large areas. Mortality of lodgepole pine in 1977 was estimated at 1,891,510 $\pm$ 194,804 trees, and 27,001 M $\pm$ 3682 M cubic feet of volume. These estimates differed somewhat from a multistage aerial photo survey also conducted in 1978, the difference ascribed to different areas of coverage. Physical characteristics of this unconventional format are described, and suggestions for its future use in similar bark beetle damage surveys are recommended.

Klein, W. H., D. L. Parker, and C. E. Jensen. 1978. Attack, emergence, and stand depletion trends of the mountain pine beetle in a lodgepole pine stand during an outbreak. Env. Entomol. 7:723-7.

ABSTRACT

Yearly trends of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) mortality in relationship to attacking and emerged mountain pine beetle (*Dendroctonus ponderosae* Hopkins) populations were measured during the life span of an epidemic within a square-mile area.

Epidemic levels of infestation were recorded for 7 yr. with peak tree killing occurring the 4th yr. More small trees were killed than large ones, but in proportion to their occurrence the large trees were killed 1st and at a higher rate.

Both density and total numbers of attacking and emerged beetle populations exhibited marked changes during the course of the epidemic. The patterns of total attacking and emerging beetle populations were similar to the trend of annual tree mortality, but population densities expressed on a square-foot basis showed different trends. Generally, the density of attacking beetles

increased during the epidemic, and while emergence remained relatively stable during the build-up years, it declined rapidly during and following the peak year of tree killing. Up to and including the year of maximum tree killing, trees of all sizes produced more beetles than they absorbed, but approached or fell below a hypothetical 1:1 emergence-attack ratio during the waning years of the outbreak. A greater percentage of emerged beetles became established in host trees during the build-up and peak year of the infestation than during the declining years.

Klein, W. H., L. E. Stipe, and L. V. Frandsen. 1972. How damaging is a mountain pine beetle infestation? A case study. USDA For. Serv., Br. For. Insect and Dis. Prev. and Cont., Ogden, UT, 7 pp.

Klein, W. H. and A. C. Tegethoff. 1970. Forest insect and disease conditions in the Intermountain states during 1969. USDA For. Serv., Int. Mtn. Reg., 11 pp.

Knight, F. B. 1958. Methods of surveying infestation of the Black Hills beetle in ponderosa pine. For. Sci. 4:35-41.

Knight, F. B. 1959. Partial life tables for the Black Hills beetle. J. Econ. Entomol. 52:1199-1202.

ABSTRACT

Life tables have been developed for use in ecological studies of Black Hills beetle (*Dendroctonus ponderosae* Hopk.) populations. These tables reveal very high mortalities among the developing beetles for all classes of infestations. Decreasing infestations suffer more than 99% mortality; static infestations about 97% and increasing infestations more than 90%. The critical mortality period is between April and July of the spring following the initial attack on the trees, late in the life cycle of the insect.

Knight, F. B. 1959. Measuring trends of Black Hills beetle infestations. USDA For. Serv. Res. Note RM-37, 6 pp.

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Knight, F. B. and F. M. Yasinski. 1956. Incidence of trees infested by the Black Hills Beetle. USDA For. Serv. Res. Note 21, 4 pp.

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Kovacic, D. A., M. I. Dyer and A. T. Cringan. 1985. Understory biomass in ponderosa pine following mountain pine beetle infestation. For. Ecol. & Mgmt. 13:53-67.

ABSTRACT

Understory herbaceous biomass was estimated in a chronosequence of ponderosa pine sites. Sites represented recovery ages ranging from 0 to 10 years after attack by the mountain pine beetle. Total understory biomass peaked on 5-year-old (5 years post-attack) sites. Five-year-old site means ranged from 102 to 201 g $m^{-2}$. Biomass gradually declined through 10 years post-attack; however, understory biomass levels remained considerably greater than those of non-infested live stands. The dominant vegetation classes (forbs, grasses, and sedges) all followed a similar biomass trend with time. Shrub biomass was too heterogeneous to measure accurately. Polynomial regressions of site biomass means plotted against time revealed a relatively poor fit. Therefore, multiple linear regression models of understory biomass were developed using measurements of time since beetle-attack, canopy opening, litter, duff, slope, insolation, basal area and mean tree diameter.

Kulhavy, D. L., A. D. Partridge and R. W. Stark. 1978. Mountain pine beetle and disease management in lodgepole pine stands: Inseparable. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 177-81.

ABSTRACT

Pest management strategies addressing only the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) may lead to recurrence of mountain pine beetle, occurrence of associated insects and expansion of disease problems. The roles of diseased lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) and of lodgepole pine with flooded root zones acting as triggers of mountain pine and associated bark beetle population build-ups are presented. Silvicultural treatments for dwarf mistletoe, and to a lesser extent for the rusts and root disturbances, are presented in the context of mountain pine beetle management. We conclude that the forest manager must consider the consequences of any silvicultural prescriptions on diseases and insects.

Kulhavy, D. L., A. D. Partridge, and R. W. Stark. 1984. Root diseases and blister rust associated with bark beetles (Coleoptera: Scolytidae) in western white pine in Idaho. Env. Entomol. 13:813-7.

ABSTRACT

Root systems of western white pine, *Pinus monticola* Douglas, were excavated with explosives and examined for pathogens. Data were also recorded on portions of the crown killed by blister rust caused by *Cronartium ribicola* Fisch. Statistical tests revealed a significant association between the bark beetles *Dendroctonus ponderosae* Hopkins and *Pityogenes fossifrons* (LeConte) and the root pathogen *Armillariella mellea* (Vahl. ex Fr.) Karst and between beetles and all root diseases. Ninety-two percent of the trees attacked by bark beetles had root diseases and 97% had either root diseases or blister rust. A discriminant analysis correctly classified 88% of the sample trees into two categories, trees infested with *D. ponderosae* or trees not infested with *D. ponderosae*, using the variable age (stump), diameter at 1.3 m in height, and percentage of the primary roots infected with pathogens. Major pathogenic organisms isolated from the roots included *A. mellea*, *Phaeolus schweinitzii* (Fr.) Pat., *Resinicium bicolor* (Fr.) Parm., *Verticicladiella* spp., and a *Europhium* strain. A hypothetical sequence of host tree invasion by blister rust, followed by infection by root diseases, and finally attacks by bark beetles, is postulated.

Landis, T. D. and R. H. Frye. 1974. Tree injury and mortality in the Dillon-Keystone area, Dillon Ranger District, White River National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-74-16, 7 p.

Lanier, G. N. and D. L. Wood. 1968. Controlled mating, karyology, morphology, and sex ratio in the *Dendroctonus ponderosae* complex. Ann. Entomol. Soc. Am. 61:517-26.

ABSTRACT

Laboratory mating experiments and observations on developmental rate, karyology, and morphology confirm the recent synonymy of *Dendroctonus monticolae* Hopkins with *D. ponderosae* Hopkins, but establish the species integrity of *D. jeffreyi* Hopkins, also previously considered a synonym of *D. ponderosae*. *D. monticolae* from British Columbia and 8 California localities were interfertile and morphologically similar. *D. ponderosae* from Colorado were interfertile with *monticolae* from California, but their mean pronotal widths, 2.44 mm and 2.10 mm, respectively, and indices of pronotal punctation, 5.43 and 6.12, respectively, were very significantly different. *D. monticolae* and its hybrid with *ponderosae* showed the karyotypic formula 11AA + Neo-XY.

*D. jeffreyi* is larger (pronotal width = 2.63 mm) and its pronotum less densely punctured (index - 4.19) than *monticolae* and *ponderosae*. The karyotype of *jeffreyi* is also 11A + Neo-XY, but the Neo-X is usually constricted and 1.4 times longer than the Neo-Y while the Neo-X of *monticolae* is rarely constricted and only slightly larger than the Neo-Y. In addition, a tiny supernumerary chromosome was present in some *jeffreyi*. In reciprocal pairings of *monticolae* and *jeffreyi*, none of the 846 eggs laid by 21 *monticolae* females hatched, but 8 larvae and 1 sterile female resulted from 362 eggs laid by 10 *jeffreyi* females. Five pairings of *jeffreyi* and *ponderosae* produced no brood.

Several *jeffreyi* (control) pairings showed a marked reduction in egg hatchability and only female progeny were produced. A male-lethal factor attacking the embryos is suggested, but pedigree data are insufficient to determine whether chromosomal or cytophasmic factors are involved.

Larsson, S., R. Oren, R. H. Waring, and J. W. Barrett. 1983. Attacks of mountain pine beetle as related to tree vigor of ponderosa pine. For. Sci. 29:395-402.

ABSTRACT

The relationship between tree vigor, measured as stem growth per unit of leaf area, and susceptibility to mountain pine beetle attacks was examined in a stocking-level experiment of ponderosa pine (*Pinus ponderosa* Laws.) in central Oregon. Vigor decreased as both tree density (basal area) and leaf area index increased. Low vigor trees were more often attacked by beetles than high vigor trees. Attacks increased below a vigor threshold of about 100 g of wood produced per square meter of leaf area per year, corresponding in this study to a basal area of 21 $m^2ha^{-1}$ or a leaf area index of 2.9 $m^2m^{-2}$. For management of ponderosa pine, maintaining vigor through thinning will reduce the risk of mountain pine beetle attacks.

Laut, J. G. 1981. Mountain pine beetle: A strategy for success. Colo. St. Univ., Colo. For. Prod. Market. Bull. 15.

ABSTRACT

Mountain pine beetle (MPB), a native insect that attacks pine trees, has killed tens of millions of ponderosa pines on approximately 500,000 acres of Front Range forests over the last decade.

Lessard, G. 1979. Biological Evaluation. Mountain pine beetle Project #632 progress report, Black Hills National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-79-11, 9 p.

Lessard, G. 1979. Biological Evaluation. Mountain pine beetle, Bear Lodge Mountains, Black Hills National Forest - 1979. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-79-12, 7 pp.

Lessard, G. 1979. Biological Evaluation. Mountain pine beetle, South Dakota State Progress Report #1-1979. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-79-15, 8 pp.

Lessard, G. 1981. Biological Evaluation. Mountain pine beetle evaluation state, county and private lands, Casper Mountain, Wyoming - 1981. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-82-1, 12 pp.

Lessard, E. D. 1982. Interim Report. Mountain pine beetle evaluation, ponderosa pine stand risk rating using ground and aerial photographic surveys - 1981. USDA For. Serv., Rocky Mtn. Reg., 16 pp.

Lessard, Gene. 1982. Factors affecting ponderosa pine stand susceptibility to mountain pine beetle in the Black Hills-1981. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. No. R2-26, 16 pp.

Lessard, Gene. 1984. Biological Evaluation. Mountain pine beetle in the Black Hills of South Dakota and Wyoming-1984. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-84-7.

Lessard, Gene. 1984. High Country Integrated Pest Management Project post-suppression evaluation, Grand County, Colorado, 1984. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-84-9, 26 pp.

Lessard, G. 1985. High Country Integrated Pest Management Project post-suppression evaluation - 1985. USDA For. Serv., Rocky Mtn. Reg. Rept. No. R2-85-4, 17 pp.

Lessard, G. and D. W. Johnson. 1981. Biological Evaluation. Mountain pine beetle, dwarf mistletoe, comandra rust in lodgepole pine, Roaring Fork and North Fork drainages, Little Snake River, Medicine Bow National Forest - 1981. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-81-4, 20 pp.

Lessard, G., D. W. Johnson, T. E. Hinds, and W. H. Hoskins. 1985. Association of Armillaria root disease with mountain pine beetle infestations on the Black Hills National Forest, South Dakota. USDA For. Serv., Methods Application Group, Rept. No. 85-4, 6 pp.

Light, J. T. and W. B. Burbridge. 1985. Effects of outbreaks and management responses on big game and other wildlife. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv., Gen. Tech. Rept. INT-174, pp. 37-43.

Lindgren, B. S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). Can. Entomol. 115:299-302.

ABSTRACT

The multiple funnel trap, an efficient, collapsible, non-sticky trap for scolytid beetles, consists of a series of vertically aligned funnels with a collecting jar at the bottom. The trap compared favorably with sticky traps and Scandinavian drainpipe traps for three species of ambrosia beetles and the mountain pine beetle. Minimum maintenance required for this trap allows for high efficiency in pheromone-based research, survey, and mass trapping of scolytid beetles.

Lindgren, S. 1983. Mountain pine beetle technical bulletin. Vancouver, B. C.:PMG/Stratford Projects Ltd., 4 pp.

Lister, C. K. 1971. Biological Evaluation. Mountain pine beetle. Routt National Forest, private land, Bureau of Land Management, Glenwood District, North Park, Colorado. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-2, 2 pp.

Lister, C. K. 1971. Biological Evaluation. Mountain pine beetle. Arapaho National Forest, Fraser and Sulphur Ranger Districts; Bureau of Land Management, Glenwood District; private land. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-4, 3 pp.

Lister, C. K. 1972. Biological Evaluation. Mountain pine beetle. Bighorn National Forest, Tongue Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-17, 2 pp.

Lister, C. K. 1972. Biological Evaluation . Mountain pine beetle. North Park, Colorado, Routt National Forest, Bureau of Land Management, and private land. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-20, 2 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Routt National Forest, Hahns Peak Ranger District, Harrison Creek. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-1, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Routt National Forest, Bears Ears Ranger District, Willow Creek. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-2, 2 pp.

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Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Arapaho National Forest and Bureau of Land Management, Granby-Middle Park. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-9, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. Forest Service, National Park Service, Bureau of Land Management, State and private lands, Black Hills, South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-10, 3 pp.

Lister, C. K. 1973. Biological Evaluation. Mountain pine beetle. White River National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-18, 3 pp.

Lister, C. K. 1978. Biological Evaluation. Mountain pine beetle. Evaluation of the proposed Beulah Cooperative Management Demonstration Area, Pike and San Isabel National Forests. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-5, 4 pp.

Lister, C. K. 1981. Biological Evaluation. Mountain pine beetle outbreak, Holy Cross Ranger District, White River National Forest. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-81-3, 15 pp.

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Lister, C. K. and D. Leatherman. 1978. Biological Evaluation. Mountain pine beetle - Evaluation of the proposed Beulah Cooperative Management Demonstration Area. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-78-5, 4 pp.

Lister, C. K. and R. W. Young. 1981. 1979 Colorado Front Range mountain pine beetle survey. USDA For. Serv., Rocky Mtn. Reg., Tech. Rept. R2-22, 19 pp.

ABSTRACT

A multistage survey to estimate tree mortality and volume on a statewide basis for Colorado was conducted in 1979. The survey methods are outlined in this report. The estimated number of faders (1978 attacked trees) was 327,443 trees from an infested area of 350,279 acres with an associated volume of 5.1 million cubic feet. Fader estimates and volumes pro-rated by ownership class are displayed for Colorado 1979 in the following table.

| | Outbreak Area (M acres) | Number of trees (M trees) | Mortality (MMCF) |
|---|---|---|---|
| Colorado | | | |
| National Forest | 177.5 | 163.5 | 2.6 |
| Other Federal | 7.0 | 6.9 | 0.1 |
| State, County or Municipal | 7.7 | 7.3 | 0.1 |
| Nonindustrial Private | 158.1 | 149.8 | 2.3 |
| Total | 350.3 | 327.5+15% | 5.1 |

Utilizing the estimate of 1979 faders (327,443) and the new mountain pine beetle infestation ratio (0.28) the estimated number of 1980 faders (1979 attacks) tree loss, was estimated to be about 92,000 ponderosa pine trees.

Logan, J. A. and G. D. Amman. (In press). A distribution model for egg development in mountain pine beetle. Can. Entomol.

Lotan, J. E., J. K. Brown and L. F. Neuenschwander. 1985. Role of fire in lodgepole pine forests. In D. M. Baumgartner, R. G. Krebill, J. T. Arnott and G. F. Weetman (eds.). Lodgepole pine - the species and its management. Symp. Proc., Coop. Ext. Wash. State Univ., pp. 133-52.

ABSTRACT

Fire is one of the most important factors involved in the establishment and development of many lodgepole pine forests in North America. In the Rocky Mountains lodgepole pine is usually considered a fire-maintained seral type. But even here fires vary greatly in frequency, intensity, size, and other characteristics. A particular fire regime greatly affects forest succession, longevity of the species, stocking, and species composition; and fire also influences the incidence of insects and diseases. Fuel quantity changes over time and with it fire behavior potentials in natural and slash fuels. Fire behavior potentials are greatest when buildup of dead fuel coincides with development of understory conifers. Most fires are low intensity, creeping, surface fires, but high intensity crown fires during severe weather burn the most acreage. Fires, stand development, mortality influences, and fuel accumulation interact in a complex network. Sound management of lodgepole pine requires that we understand the complexities of lodgepole pine ecology, including the role of fire, and manage fire within that context.

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Mahoney, R. L. 1978. Lodgepole pine/mountain pine beetle risk classification methods and their application. In A. A. Berryman, G. D. Amman, R. W. Stark, and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 106-13.

ABSTRACT

Four mountain pine beetle (*Dendroctonus ponderosae* Hopkins)/lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) stand risk classification methods are tested. Their

application to management is discussed. The 24 lodgepole pine test stands were located in central Idaho and western Montana. A combination of the methods tested provides improved predictions of mountain pine beetle infestations, a better understanding of host/beetle interactions, and practical alternatives for lodgepole pine/mountain pine beetle management.

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* Manning, G. H. et al. 1982. A review of mountain pine beetle problems in Canada. Canada Dept. Env., Can. For. Serv., Pac. For. Res. Cent., 27 pp.

* Massey, C. L. 1951. Heights of treatment of the Black Hills beetle in ponderosa pine and the relation of height of infestation to DBH, Roosevelt National Forest, 1950. USDA Bur. Entomol., Fort Collins, CO.

Massey, C. L., R. D. Chisholm and N. D. Wygant. 1953. Ethylene dibromide for control of Black Hills beetle. J. Econ. Entomol. 46:601-4.

Massey, C. L. and N. D. Wygant. 1949. An analysis of seasonal precipitation records as related to Black Hills beetle outbreaks. USDA Bur. Entomol. and Plant Quar., Fort Collins, CO, 7 pp.

* Massey, C. L., N. D. Wygant, and R. I. Washburn. 1950. Tests with ethylene dibromide emulsions for control of the Black Hills beetle in ponderosa pine. USDA Bur. Entomol., Fort Collins, CO.

Mata, S. A., Jr. 1972. Accuracy of determining mountain pine beetle attacks in ponderosa pine utilizing pitch tubes, frass, and entrance holes. USDA For. Serv. Res. Note RM-222, 2 pp.

ABSTRACT

Counts of external indicators of attacks by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, throughout the infested length of five sampled ponderosa pines, where 1.5 percent greater than actual attacks.

Matson, P. A. and F. P. Hain. 1983. Host conifer defense strategies: a hypothesis. In L. Safranyik (ed.). The role of the host in the population dynamics of forest insects. proc. of IUFRO Conf., Banff, Alberta, Can., pp. 33-42.

ABSTRACT

Pines use several mechanisms in the defense against stem-invading insects. We speculate that the relative importance of each mechanism differs with pine species, and can be related to differences in insect pressure. Pines subject to many (2-10) asynchronous beetle generations annually may rely more heavily on a constitutive, preformed primary resin system. On the other hand, species which defend against few and synchronous beetle generations each year may rely more on an inducible and localized hypersensitive response. We suggest that the preformed resin system, while energetically expensive, is less costly than hypersensitive response would be if continuously induced.

McBride, J. K. 1982. The need for action against mountain pine beetle on commercial timber and related lands. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv., Rept. BC-X-230, pp. 47-49.

McCambridge, W. F. 1962. Sexing Black Hills beetles, *Dendroctonus ponderosae* Hopkins. Ann. Entomol. Soc. Am. 55:723-4.

McCambridge, W. F. 1964. Emergence period of Black Hills beetles from ponderosa pine in the Central Rocky Mountains. USDA For. Serv. Res. Note RM-32, 4 pp.

McCambridge, W. F. 1967. Nature of induced attacks by the Black Hills beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). Ann. Entomol. Soc. Am. 60:920-8.

ABSTRACT

Attractants of *Dendroctonus ponderosae* Hopkins, made by attaching infested bolts to green trees or forcing attacks on such trees under screen cages, provided a means to study how the beetle attacks trees and stands. Attractant trees were always infested first; first attacks occurred below 8 ft., and generally below 4 ft. Initial attacks on adjacent trees, which occurred during the mass attack, appeared slightly higher on the trees but not higher than 10 ft. Subsequent attacks occurred below and above the initial attacks, with the mean height increasing with time. Trees became infested at progressively greater distances from the attractant center. Infested trees were significantly larger than green trees within the radius of infestation. The greatest number of attacks was recorded at the end of the 4 pm to 6 am period.

McCambridge, W. F. 1968. Attraction of Black Hills beetle to ponderosa pine in the Central Rocky Mountains. N. Cent. Br. Entomol. Soc. Am. Proc. 23:137-40.

ABSTRACT

Infestations of Black Hills beetles can be established in preselected locations by the attraction produced from forced attacks to a small number of beetles. This procedure has made possible detailed observations on how trees and stands become attacked. Practical applications and limitations are discussed.

McCambridge, W. F. 1969. Spermatozoa in unemerged female mountain pine beetles, *Dendroctonus ponderosae* Hopk. Entomol. Soc. Ontario Proc. 100:168-70.

ABSTRACT

Less than 2% of the female mountain pine beetles found grouped under the bark of ponderosa pine contained spermatozoa just prior to emergence. Within three days after emergence into standard collection jars, 15% of these same populations contained sperm. Mating in the jars is suspected.

McCambridge, W. F. 1969. Incidence of sperm in emerging female mountain pine beetles. USDA For. Serv. Res. Note RM-137, 3 pp.

ABSTRACT

Approximately 15 percent of female mountain pine beetles, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), examined during the normal brood emergence period from field-infested ponderosa pine contained spermatozoa. In laboratory tests where parent females were accounted for, less than 2 percent of brood females contained sperm.

McCambridge, W. F. 1971. Temperature limits of flight of mountain pine beetle (*Dendroctonus ponderosae*). Ann. Entomol. Soc. Am. 64:534-5.

McCambridge, W. F. 1972. Treatment height for mountain pine beetles in Front Range ponderosa pine. USDA For. Serv. Res. Note RM-218, 2 pp.

ABSTRACT

Pitch tubes and intermittent blue stain are generally found about 5 feet above the highest point where significant mountain pine beetle brood is produced; thus, chemical control can be achieved by spraying to 5 feet below the highest pitch tubes.

McCambridge, W. F. 1974. Influence of low temperatures on attack, oviposition, and larval development of mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). Can. Entomol. 106:979-84.

ABSTRACT

Mountain pine beetles attacked logs, mated, and constructed egg galleries slowly at 4.4°C under laboratory conditions. No eggs were deposited in 6 weeks. Attack and oviposition increased above this temperature.

Larvae of different initial sizes grew at the same rate throughout each test temperature from 4.4°C to 12.8°C. Rate of growth increased with increase in temperature. Larval growth at 2.2°C is difficult to prove because of very high mortality among smallest individuals.

McCambridge, W. F. 1974. Identifying ponderosa pines infested with mountain pine beetles. USDA For. Serv. Res. Note RM-273, 2 pp.

ABSTRACT

Trees successfully and unsuccessfully attacked by mountain pine beetles have several symptoms in common, so that proper diagnosis is not always easy. Guidelines presented here enable the observer to correctly distinguish nearly all attacked trees.

McCambridge, W. F. 1975. Scotch pine and mountain pine beetles. Green Thumb 32:87.

McCambridge, W. F. 1980. Some mountain pine beetle infestation characteristics in dwarf mistletoe-infected and uninfected ponderosa pine. USDA For. Serv. Res. Note RM-391, 2 pp.

ABSTRACT

There were no significant differences in attacks or brood production between heavily infected and uninfected trees. Total egg gallery length per unit of bark area was greater in uninfected trees.

McCambridge, W. F. 1981. Duration of effectiveness of Carbaryl in protecting ponderosa pines from attack by mountain pine beetles. UDSA For. Serv. Res. Note RM-408, 3 pp.

ABSTRACT

Two percent carbaryl spray provided minimally acceptable protection of ponderosa pines from mountain pine beetle attacks 13 months after application. At 4% strength, protection was satisfactory for 15 months, as tested by laboratory bioassay.

McCambridge, W. F. 1982. Effectiveness of thinning ponderosa pine stands in reducing mountain pine beetle-caused tree losses in the Black Hills: preliminary observations. USDA For. Serv. Res. Note RM-414, 3 pp.

ABSTRACT

Three ponderosa pine stands thinned to less than 90 square feet stem basal area per acre sustained little tree mortality from mountain pine beetle attacks, while adjacent, unthinned stands continued to be affected. These results are consistent with subjective observations that thinning dense, second-growth ponderosa pine is effective in preventing unacceptable levels of beetle-caused tree mortality in the Black Hills.

McCambridge, W. F. 1982. Field tests of insecticides to protect ponderosa pine from the mountain pine beetle (Coleoptera: Scolytidae). J. Econ. Entomol. 75:1080-2.

ABSTRACT

Individual ponderosa pines, *Pinus ponderosa* Lawson, can be protected from *Dendroctonus ponderosae* Hopkins attacks by spraying the boles with 2% carbaryl-water suspension. Although lindane emulsion at 2% gives equal protection, numerous pitch tubes leave trees cosmetically inferior. Other dose rates and materials are considered inferior. Insecticides tested kill a broad spectrum of insects, including predators of the mountain pine beetle. Predators may have been attracted to certain insecticide formulations.

McCambridge, W. F., G. D. Amman and G. C. Trostle. 1979. Mountain pine beetle. USDA For. Serv. Insect and Disease Leafl. (revised), 7 pp.

McCambridge, W. F., F. G. Hawksworth, C. B. Edminster and J. G. Laut. 1982. Ponderosa pine mortality resulting from a mountain pine beetle outbreak. USDA For. Serv. Res. Paper RM-235, 7 pp.

ABSTRACT

From 1965 to 1978, mountain pine beetles killed 25% of the pines taller than 4.5 feet in a study area in north-central Colorado. Average basal area was reduced from 92 to 58 square feet per acre. Mortality increased with tree diameter up to about 9 inches d.b.h. Larger trees appeared to be killed at random. Mortality was directly related to number of trees per acre and presence of dwarf mistletoe, but not to site index, elevation, or percent Douglas-fir in the stand.

McCambridge, W. F., J. Laut and R. Gosnell. 1975. Fumigate firewood infested with mountain pine beetle. USDA For. Serv. Res. Note RM-289, 2 pp.

ABSTRACT

Beetles in ponderosa pine firewood can be killed by spraying each cord with 2 gallons of ethylene dibromide emulsion then covering and sealing the piles with plastic.

McCambridge, W. F. and S. A. Mata, Jr. 1969. Flight muscle changes in Black Hills beetles, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), during emergence and egg laying. Can. Entomol. 101:507-12.

ABSTRACT

The lateralis medius, an indirect flight muscle of Black Hills beetles, degenerated abruptly in females within 3 days after attack. Egg laying began at the end of the 3 days. Thickness of the muscle changed much more than width. Regeneration began in most ovipositing females about 10 days after attack. Steady development of the muscle to its maximum size, reached prior to beetle emergence, offers a method of forecasting emergence.

McCambridge, W. F., M. J. Morris, and C. B. Edminster. 1982. Herbage production under ponderosa pine killed by the mountain pine beetle in Colorado. USDA For. Serv. Res. Note RM-416, 3 pp.

ABSTRACT

Herbage growth increased steadily over 4 years, beginning the year after beetle attack. Yields of forbs, sedges, and grasses contributed most to gains of between a quarter and a half ton per acre of dry herbage. Yields of herbage were not increased in the shade of saplings where overstory trees were killed by beetles. Rapid herbage growth and the mulch provided by fallen dead pine needles appeared to help prevent soil erosion.

McCambridge, W. F. and G. C. Trostle. 1972. The mountain pine beetle. USDA For. Serv., For. Pest Leaflet 2, 6 pp. (rev.)

McClelland, W. T., F. P. Hain, C. J. DeMars, W. S. Fargo, R. N. Coulson and T. E. Nebeker. 1978. Sampling bark beetle emergence: A review of methodologies, a proposal for standardization, and a new trap design. Bull. Entomol. Soc. Am. 24:137-40.

McCord, P. P. and C. L. Massey. 1948. Black Hills insect control project - 1948. USDA Bur. Entomol. and Plant Quar., Fort Collins, CO.

McGhehey, J. H. 1968. Territorial behavior of bark-beetle males. Can. Entomol. 100:1153.

* McGhehey, J. H. 1969. Sex ratios of individual broods of the mountain pine beetle. Bi-Mon. Res. Notes, Ottawa 25:2.

* McGhehey, J. H. 1971. Female size and egg production of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, N. For. Res. Cent., Edmonton, Alberta, Inf. Rept. NOR-X-9, 18 pp.

McGregor, M. D. 1972. Effect of thinning second-growth ponderosa pine on incidence of mountain pine beetle infestation - Establishment Report. USDA For. Serv. Northern Reg., Rept. No. I-72-3, 5 pp.

McGregor, M. D. 1973. Effect of thinning second-growth ponderosa pine stands on incidence of mountain pine beetle infestation - Progress report. USDA For. Serv., Northern Reg., Rept. No. 73-6, 5 pp.

McGregor, M. D. 1973. Status of mountain pine beetle, Gallatin Ranger District, Gallatin National Forest. USDA For. Serv., Northern Reg., Rept. No. 73-9, 7 pp.

McGregor, M. 1973. Cultural control of mountain pine beetle in second-growth ponderosa pine stands, Lolo National Forest. USDA For. Serv., Northern Reg., Rept. No. 73-14, 6 pp.

McGregor, M. D. 1974. Status of mountain pine beetle infestations, Gallatin District, Gallatin National Forest - 1973. USDA For. Serv., Northern Reg., Rept. No. 74-17, 12 pp.

ABSTRACT

Mountain pine beetle infestations have continued at epidemic level in lodgepole pine stands since 1969 in the West Gallatin River drainage. This infestation has increased at about a 1.9:1 buildup ratio annually. Since the outbreak began in 1969, surveys indicate that approximately 22,354 merchantable size trees have been killed with an estimated volume loss of 1,061 MMBF. This is a total of about 27 percent of the merchantable lodgepole pine within areas surveyed. Additional tree mortality and volume loss have occurred, but not all infested areas were surveyed due to land exchange between Big Sky Corporation, Burlington Northern Railroad, and the Forest Service.

Operational control of felling and burning, and salvage logging of infested trees was initiated in 1971. This action did little to slow the impetus of the outbreak, because the complete infestation could not be suppressed. The outbreak is expected to continue at epidemic levels in 1974, with an increase in the number of infested trees. A cooperative administrative study between the Northern Region and Intermountain Forest and Range Experiment Station is planned in fiscal year 1975 to determine if silvicultural methods can be used to control mountain pine beetle in mature and overmature overstocked lodgepole pine stands on the Gallatin National Forest.

* McGregor, M. D. 1978. Status of mountain pine beetle infestations, Kootenai National Forest, Montana, 1977. USDA For. Serv., Northern Reg., Rept. No. 78-8, 12 pp.

ABSTRACT

Mountain pine beetle populations increased to epidemic levels on the Kootenai National Forest in 1972. Nearly 397,000 trees containing almost 32 million board feet have been killed. More than 84,000 trees will probably be killed in 1978. Infestation has the potential to intensify in high hazard stands, and some increase may occur in stands of low and moderate hazard. Potential losses can be reduced through an accelerated program of (1) sanitation salvage cutting and (2) silvicultural management. High-hazard stands should receive first priority.

McGregor, M. D. 1978. Management of mountain pine beetle in lodgepole pine stands in the Rocky Mountain Area. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 129-39.

ABSTRACT

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins) is the primary bark beetle influencing management of lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann). Management by chemical treatment and by felling and burning of infested trees or salvage logging are rearguard techniques and do not prevent or reduce anticipated tree mortality. Methods are available for risk rating susceptible stands so management can be directed toward highest hazard stands. Characteristics such as slope, aspect, elevation, tree diameter, percent of lodgepole pine basal area with mistletoe infection, percent of lodgepole pine basal area in the stand and habitat type should be considered when risk rating stands. Suggested management strategies are discussed for areas designated for timber production, for individual trees of high value and for non-timber values.

McGregor, M. D. 1979. A demonstration of lodgepole pine management to prevent mountain pine beetle outbreaks, Yaak and Thompson River Drainages. Progress Report. USDA For. Serv., Northern Reg. Rept. No. 79-14, 3 pp.

McGregor, M. D. 1982. The current situation of the mountain pine beetle in the United States and the resources involved. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 16-21.

McGregor, M. D. 1985. Concepts for evaluating susceptibility of managed stands. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv., Gen. Tech. Rept. INT-174, pp. 30-1.

McGregor, M. D. 1985. Soil and Water Quality. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv., Gen. Tech. Rept. INT-174, pp 44.

McGregor, M. D. 1985. Landscape and visual management concerns. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp 44.

McGregor, M. D. 1986. Stand hazard and risk rating for mountain pine beetle susceptibility and losses. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 87-101.

McGregor, M. D., G. D. Amman, and W. E. Cole. 1981. Hazard rating lodgepole pine for susceptibility to mountain pine beetle infestation. In R. L. Hedden, S. J. Barras, and J. E. Coster (eds.). Hazard rating systems in forest pest management. USDa For. Serv. Gen. Tech. Rept. WO-27, pp. 99-104.

ABSTRACT

Montana stands of lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann, were rated using Amman's system for risk of infestation by mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Hazard rating was based on three factors--climate suitability of the stand, average d.b.h., and average tree age. The system helped direct land managers to susceptible stands where harvest of trees is reducing losses to the beetles. During the 5 years following rating, 11 percent of the high-hazard stands became infested; only 1 percent of the stands rated moderate became infested; and less than 1 percent of the stands rated light became infested.

McGregor, M. D. and M. J. Berg. 1973. Evaluation of mountain pine beetle infestations - Yellowstone National Park, Wyoming, 1972. USDA For. Serv., Northern Reg., Rept. No. 73-4, 5 pp.

ABSTRACT

The mountain pine beetle, *Dendroctonus ponderosae* Hopk., infestation advanced north and eastward from the 1971 infestation boundary in Yellowstone National Park. Infested trees were found in Indian Creek campground at the north end of the park and around the north end of Yellowstone Lake. A ground survey showed an average of 15.5 infested trees per acre. A decrease in number of infested trees occurred in older infestation centers in the southwest corner of the park. The infestation will continue at epidemic status in areas containing susceptible stands.

McGregor, M. D., W. E. Bousfield, R. D. Lood and H. E. Meyer. 1974. Mountain pine beetle impact survey Ninemile Drainage, Lolo National Forest, and State and private lands, Montana - 1973. USDA For. Serv., Northern Reg., Rept. No. 74-22, 8 pp.

ABSTRACT

The mountain pine beetle reached epidemic levels in second-growth 80-year-old ponderosa pine stands on the Ninemile Ranger District in 1969. The outbreak increased through 1971 and spread over 30,000 acres. Heavy infestation occurred on about 2,600 acres within this area. A two-stage survey was used during 1972 and 1973 to stratify the infestation, and obtain tree and volume loss estimates. This survey shows that about 109,284 trees were killed with an estimated volume loss of 613,743 board feet from 1970 to 1973. The outbreak has been declining since 1971. Surveys this year point toward a continued decline. However, some "hot spot" infestations will persist in pure, overstocked, second-growth stands. Commercial thinning is encouraged to release the stand, promote tree growth, and change the microenvironment, making it unattractive to mountain pine beetle.

McGregor, M. D. and D. M. Cole. 1985. Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, 68 pp.

ABSTRACT

Guidelines are presented to assist forest managers in integrating pest management techniques for the mountain pine beetle (*Dendroctonus ponderosae* Hopk. with other resource considerations in the process of planning and executing balanced resource management of lodgepole pine (*Pinus contorta* var. *latifolia*) forests. The guidelines summarize published and unpublished technical information and recent research on the ecological interaction of pest and host and present visual and

classification criteria and methods for recognizing and summarizing occurrence and susceptibility status of lodgepole pine stands according to habitat types and successional roles and important resource considerations associated with them. Information is summarized for appropriate silvicultural systems and for practices that address significant resource concerns of commercial and noncommercial forest land designations and wilderness and other special administrative areas. A data acquisition, data analysis, and decision framework is presented for integrating management of mountain pine beetle populations with multiple resource management of lodgepole pine forests.

McGregor, M. D. and D. M. Cole. 1985. Integrating pest management for the mountain pine beetle with management for multiple-resource goals. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 60-2.

McGregor, M. D. and D. M. Cole. 1985. Practices and considerations for noncommercial forests. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 56-9.

McGregor, M. D. and J. E. Dewey. 1971. Evaluation of mountain pine beetle infestations on the Squaw Creek Ranger District, Gallatin National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 71-14, 4 pp.

McGregor, M. D., K. E. Gibson, and R. D. Oakes. 1982. Status of mountain pine beetle infestations, Flathead National Forest and other portions of Montana. USDA For. Serv., Northern Reg., Rept. No. 82-6, 20 pp.

McGregor, M. D., K. E. Gibson, S. Tunnock and L. E. Stipe. 1985. Status of mountain pine beetle infestations, Northern Region, 1984. USDA For. Serv., Northern Reg., Rept. No. 85-25, 57 pp.

ABSTRACT

Mountain pine beetle infestations surged upward on the Bitterroot, Custer, Deerlodge, Flathead, Helena, and Kootenai National Forests, and on the Blackfeet and Northern Cheyenne Indian Reservations in Montana, and on the Nezperce National Forest and Bureau of Land Management lands in Idaho in 1984. Infestations remained static from 1983 to 1984 on the Lolo National Forest and declined on the Beaverhead and Gallatin National Forests, in Glacier and Yellowstone National Parks, on the Crow, Flathead, Fort Belknap, and Rocky Boy's Indian Reservations, and on Bureau of Land Management lands in Montana.

A continued decline is predicted due to host depletion in most areas for infestations on the Beaverhead and western portion of the Gallatin National Forests, in Glacier and Yellowstone National Parks, and on the Blackfeet Indian Reservation in 1985.

In 1985 infestations are predicted to increase in lodgepole and/or ponderosa pine types on the Bitterroot, Custer, Deerlodge, Flathead, Helena, Kootenai, Lewis & Clark, and Lolo National Forests, on the Crow, Flathead, Fort Belknap, Northern Cheyenne, and Rocky Boy's Indian Reservations in Montana; and on the Nezperce National Forest, Bureau of Land Management, and State and private lands in the Craig Mountains, Idaho.

McGregor, M. D., D. R. Hamel, R. C. Lood and H. E. Meyer. 1975. Status of mountain pine beetle infestations in Glacier National Park, Montana. USDA For. Serv., Northern Reg. Rept. 75-10, 7 pp.

ABSTRACT

Mountain pine beetle populations reached epidemic levels on approximately 4,600 acres in Glacier National Park in 1972. Infested trees increased from 4.9 in 1972 to 10.9/acre in 1975. Majority of trees killed since 1972 were 12 inches d.b.h. and larger in size. Sufficient large diameter lodgepole pine exists to maintain the infestation at epidemic level for several years.

McGregor, M. D., D. R. Hamel, R. C. Lood, H. E. Meyer and S. Kohler. 1975. Evaluation of mountain pine beetle infestations, Lazier and Meadow Creek Drainages, Plains District, Lolo National Forest, Montana, 1975. USDA For. Serv., Northern Reg., Rept. No. 75-17, 11 pp.

ABSTRACT

Mountain pine beetle reached epidemic levels in the Lazier-Meadow Creek drainages on mixed ownership in 1972. A total of 118,486 trees

with an estimated volume of 5,666,124 board feet was killed from 1972 through 1974. Presence of overstocked, mature, nearly pure lodgepole pine stands, coupled with favorable weather conditions, are believed to be responsible for outbreak development. Prompt salvage logging of infested and susceptible trees, and conversion to a mixed species stand, compatible with the designated habitat type and site index, are recommended to alter the course of the outbreak.

McGregor, M. D., D. R. Hamel, H. Meyer and R. Lood. 1975. Evaluation of a mountain pine beetle infestation, Fisher River Ranger District, Kootenai National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 75-2, 9 pp.

ABSTRACT

Mountain pine beetle killed approximately 14,592 lodgepole pine containing an estimated 1,033,022 board feet volume from 1972 to 1974 in the Calx-Tamarack Creek drainage. This is approximately 8 percent of the lodgepole pine stand. Buildup ratios exceeded 1:1 from 1972-73 to 1974. Based on stand structure, size of trees infested, and existing green lodgepole, it is predicted that in excess of 9,000 trees will be killed in 1975. Selective logging is recommended to reduce the infestation to endemic levels.

McGregor, M. D., D. R. Hamel and R. C. Lood. 1976. Evaluation of mountain pine beetle infestation, Gallatin Ranger District, Gallatin National Forest, Montana, 1975. USDA For. Serv., Northern Reg., Rept. 76-5, 11 pp.

ABSTRACT

Mountain pine beetle has occurred at epidemic level in lodgepole pine stands in the west Gallatin River drainage since 1969. Infestation now encompasses about 5,500 acres. Since 1969, approximately 463,212 trees, with an estimated volume of 20,529,244 board feet have been killed. Approximately 69 percent of the stands on the Gallatin District are classed as susceptible. It is predicted that about 927,781 trees will be killed in 1976. Selective logging to remove infested and susceptible trees is recommended to reduce the potential for a continued epidemic.

McGregor, M. D., D. R. Hamel and R. D. Oakes. 1977. Evaluation of mountain pine beetle infestations, Thompson River Drainage, Plains District, Lolo National Forest, Montana, 1976. USDA For. Serv., Northern Reg., Rept. No. 77-5, 8 pp.

ABSTRACT

Mountain pine beetle developed to epidemic levels in lodgepole pine stands in the Thompson River drainage in 1971. Approximately 506,616 trees are infested on 4,444 hectares. Based on buildup ratios, infestations are expected to intensify; develop in uninfested stands; and kill about 1,763,024 trees in 1977. Salvage logging of infested trees and silvicultural management to reduce the average stand diameter below 20 cm d.b.h. are recommended to manage the infestation.

McGregor, M. D. , D. R. Hamel and R. D. Oakes. 1977. Status of mountain pine beetle infestations, Gallatin National Forest--1976. Northern Reg., Rept. No. 77-12, 8 pp.

ABSTRACT

Mountain pine beetle developed to epidemic level in lodgepole pine stands in 1969 on the Gallatin District and in 1970 on the Hebgen Lake District. Epidemic infestation occurs on 53,437 hectares. Infestations will intensify in most areas currently infested and develop in uninfested stands, and in excess of 2 million trees could be killed in 1977. Salvage logging to remove brood trees and silvicultural management to reduce average stand diameter below 20.3 cm d.b.h. are recommended to manage the infestation.

McGregor, M. D. and S. Kohler. 1973. Evaluation of mountain pine beetle infestation Wolf Mountains, Crow Indian Reservation, Montana, 1973. USDA For. Serv., Northern Reg., Rept. No. 73-28, 5 pp.

McGregor, M. D., S. Kohler and G. Ferry. 1974. Evaluation of mountain pine beetle infestations, Wolf Mountains, Crow Indian Reservation, Montana, 1973. USDA For. Serv., Northern Reg., Rept. No. 74-6, 7 pp.

ABSTRACT

Mountain pine beetle reached epidemic levels in second-growth ponderosa pine stands on Bureau of Indian Affairs and private lands on the Crow Indian Reservation. Approximately 9,106 trees containing 420,266 merchantable board feet were killed from 1971 to 1973. This is about 24 percent of the merchantable ponderosa pine in stands surveyed. Stands are stagnated, and trees appear stressed which is probably predisposing them to beetle attack.

An increase in size of area infested and number of trees killed is expected in 1974. Commercial thinning to remove infested trees and reduce basal area is recommended to alleviate the problem. Slash disposal is highly recommended during logging to prevent buildup of pine engraver beetle populations.

McGregor, M. D. and R. C. Lood. 1970. Evaluation of bark beetle infestations Judith, Musselshell, and Belt Creek Ranger Districts, Lewis and Clark National Forest, Montana. USDA For. Serv., Northern Reg., 4 pp.

ABSTRACT

Static mountain pine beetle, *Dendroctonus ponderosae* Hopk., infestations were detected in ponderosa pine stands in the Big and Little Snowy Mountains, Musselshell Ranger District. Endemic conditions occur in Sage Creek-Woodhurst Mountain vicinity, and in Yogo Creek Drainage, Judith Ranger District. The infestation, active during 1968 and 1969 on Monarch Mountain, has decreased to endemic levels. Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., populations are at low levels throughout the Forest.

McGregor, M. D. and R. C. Lood. 1973. Status of bark beetle infestations in second-growth ponderosa pine stands, Bureau of Land Management lands, Garbet Mountains, Montana. USDA For. Ser., Northern Reg., Rept. No. 73-25, 5 pp.

ABSTRACT

Mountain pine beetle infestations have increased in second-growth ponderosa pine stands in the Garnet Mountains since 1971. The extremely dry 1973 season resulted in an increase of ips engraver beetle activity that was responsible for over half of the tree mortality in 1973. Commercial thinning is recommended to alleviate the problem.

McGregor, M. D. and H. E. Meyer. 1973. Evaluation of mountain pine beetle infestations, Big Belt Mountains, Townsend District, Helena National Forest--1973. USDA For. Serv., Northern Reg., Rept. No. 73-29, 5 pp.

ABSTRACT

Mountain pine beetle, *Dendroctonus ponderosae* Hopk., reached near epidemic levels in lodgepole pine stands in the Sulphur Creek-Black Butte area. Lodgepole pine are probably more susceptible due to the overstocked conditions of stands, and high incidence of girdling of the base of trees by porcupines. The infestation in this area was classified as static with a decreasing trend.

Mountain pine beetle and pine engraver beetle, *Ips* spp., increased to epidemic levels in blowdown and top-broken second-growth ponderosa pine in the North Fork of Roy and Grunett Creek drainages on State, private and Bureau of Land Management lands. Several hundred ponderosa pines are now infested. Sufficient brood is present to cause an increase in number of trees killed in 1974.

Several hundred subalpine fir were killed by the fir engraver beetle, *Scolytus ventralis* Lec., the western balsam bark beetle, *Dryocoetes confusus* Sw., and *Pityokteines* sp. Faded tree groups occur from Duck Creek Pass north to Slough Creek. Most infested groups are adjacent to current or recent logging activity that provided slash and served as a breeding site and source of population buildup.

McGregor, M. D., R. D. Oakes and H. E. Meyer. 1983. Status of mountain pine beetle, Northern Region, 1980. USDA For. Serv., Northern Reg., Rept. No. 83-16, 31 pp.

McGregor, M. D. and S. Tunnock. 1971. Status of mountain pine beetle infestations on the Hebgen Lake Ranger District, Gallatin National Forest, Montana. USDA For. Serv., Northern Reg., Rept. No. 71-45, 3 pp.

ABSTRACT

An infestation of the mountain pine beetle, *Dendroctonus ponderosae* Hopk., was detected on the Hebgen Lake District, Gallatin National Forest, Montana, during 1971. An earlier evaluation of this infestation (Ciesla, 1971) indicated that this infestation might be a portion of a larger infestation encompassing portions of the Targhee National Forest and Yellowstone National Park.

A reconnaissance survey was conducted on the Hebgen Lake Ranger District to determine the extent of mountain pine beetle infestations in the District and to establish if it was isolated or adjoined the larger Targhee-Yellowstone infestation. M. D. McGregor and Scott Tunnock, accompanied by Gene C. Lasch, Raymond A. Christensen, and Gary T. Christensen of the Hebgen Lake District conducted this survey during the period November 8-11.

McMullen, L. H. and R. E. Betts. 1982. Water sprinkling of log decks to reduce emergence of mountain pine beetle in lodgepole pine. For. Chron. 58:205-6.

ABSTRACT

Water sprinkling of lodgepole pine logs infested by mountain pine beetle with soaker-hoses on the surface of log decks, reduced survival of pupae and young adults to 5% compared with 93% in control decks. The technique provides a useful alternative to other methods of reducing hazard from the insect to pine stands surrounding log storage areas.

Michael, R. R. and J. A. Rudinsky. 1972. Sound production in Scolytidae: specificity in male *Dendroctonus* beetles. J. Insect Physiol. 18:2189-201.

ABSTRACT

The male stridulatory apparatus of six *Dendroctonus* bark beetles is described, showing species-specificity especially in the elytral files. Typical male stridulation of *D. pseudotsugae* and *D. ponderosae* at the chemostimulus of each female's attractant and at stress when handled, is found to be distinct and specific when electronically recorded.

* Michalson, E. L. 1975. Economic impact of mountain pine beetle on outdoor recreation. S. J. Agric. Econ.____:_____.

Michalson, E. L. and J. Findeis. 1979. Economic impact of mountain pine beetle on outdoor recreation. In: USDA For. Serv. Gen. Tech. Rept. WO-8, pp. 43-9.

Miller, J. M. 1924. The Black Hills beetle on the Kaibab Forest. Timber Man. 26:50.

Miller, J. M. and N. D. Wygant. 1942. Studies of physical characteristics of high and low risk ponderosa pines, Black's Mountain Experimental Forest, season of 1941. USDA Bur. Entomol., Berkeley, CA, 19 pp.

Miller, R. H. and A. A. Berryman. 1983. Energetics of conifer defense against beetles and associated fungi. In L. Safranyik (ed.). The role of the host in the population dynamics of forest insects. Proc. of IUFRO Conf., Banff, Alberta, Can., pp. 13-23.

ABSTRACT

The synthesis of monoterpenes and other defensive chemicals by conifers is a metabolically expensive process. Inoculation of lodgepole pine phloem and sapwood with *Ceratocystis clavigerum,* a symbiotic fungus associated with the mountain pine beetle, resulted in 30% decrease in soluble sugars and a 15% decrease in reducing sugars in the wound reaction area over a five-day period with no change in starch titres. The greatest decrease in sugars appeared within 24-36 hours of inoculation of fungus. Rapid increase in monoterpenes occurred in the wound response of lodgepole pine which cannot be accounted for by changes in local carbohydrate levels. Carbohydrate reserves or monoterpene precursors must therefore be translocated from adjacent tissues. Sugar and starch titres were also observed to decrease towards the end of summer in trees ultimately killed by bark beetles. Trees not attacked had a lesser depletion of phloem starch at this time. Reduced monoterpene titres in wound response of late summer in unattacked trees may result from disruption of carbohydrate translocation to the infected area.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Medicine Bow National Forest, Encampment Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-20, 3 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Roosevelt National Forest, Redfeather Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-22, 3 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Roosevelt National Forest, Poudre Ranger District. USDA For. Serv. Rocky Mtn. Reg., Rept. No. 71-23, 2 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Roosevelt National Forst, Estes Park Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-24, 2 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. South Pass City--Atlantic City, Wyoming. Federal, State, and private land. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-26, 3 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Black Hills National Forest, Bearlodge Ranger District; Bureau of Land Management; State of Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-27, 3 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Pike National Forest, South Platte Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-29, 3 pp.

Minnemeyer, C. D. 1971. Biological Evaluation. Mountain pine beetle. Roosevelt National Forest, Boulder Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No. 71-30, 2 pp.

Minnemeyer, C. D. 1972. Biological Evaluation. Mountain pine beetle. Pike National Forest, Pikes Peak Ranger District. USDA For. Serv., Rocky Mtn. Reg., Rept. No., R2-72-4, 2 pp.

Minnemeyer, C. D. 1972. Biological Evaluation. Mountain pine beetle. Granby-Middle Park, Arapaho National Forest and Bureau of Land Management. USDA For. Serv, Rocky Mtn. Reg., Rept. No. R2-72-19, 3 pp.

Minnemeyer, C. D. 1972. Biological Evaluation. Mountain pine beetle. Black Hills of South Dakota and Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-22, 4 pp.

Minnemeyer, C. D. 1972. Biological Evaluation. Mountain pine beetle. Shoshone National Forest, Bureau of Land Management, and private land, South Pass Citv--Atlantic City Area, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-72-23, 3 pp.

Minnemeyer, C. D. 1973. Biological Evaluation. Mountain pine beetle. Pike National Forest, South Platte and Pikes Peak Ranger Districts and adjacent State and private lands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-73-12, 2 pp.

Minnemeyer, C. D. 1973. The effects of mountain pine beetle in Black Hills ponderosa pine stands. USDA For. Serv., Rocky Mtn. Reg., 5 pp.

Minnemeyer, C. D. 1974. The effects of mountain pine beetle epidemics in four Roosevelt National Forest ponderosa pine stands. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-74-1, 3 pp.

Mitchell, R. G., R. H. Waring, and G. B. Pitman. 1983. Thinning lodgepole pine increases tree vigor and resistance to mountain pine beetle. For. Sci. 29:204-11.

ABSTRACT

Thinned and unthinned stands of lodgepole pine in eastern Oregon were evaluated in 1980 to determine their vigor and susceptibility to attack by outbreak populations of the mountain pine beetle. Application of a vigor rating system, based on amount of stem growth per square meter of crown leaf area, showed that thinnings from below improved vigor of residual stand and reduced beetle attack. Beetle mortality was significant in unthinned and lightly thinned stands where current annual growth of stemwood of residual trees averaged less than 80 $g/m^2$ of foliage. Stands with mean vigor ratings of about 100 were beginning to suffer beetle attack. There was no mortality in heavily thinned stands where vigor ratings exceeded 120. These findings suggest that lodgepole pine can be managed through stocking control to obtain fast-growing large-diameter trees and to avoid attack by the mountain pine beetle.

Miyagawa, R. 1986. Mountain pine beetle problems in Alberta. In Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 102-103.

Moeck, H. A. 1980. Field tests of Swedish "Drainpipe" pheromone trap with mountain pine beetle. Env. Can., Can. For. Serv., Bi-mon. Res. Notes 36:2-3.

Moeck, H. A., D. L. Wood and K. Q. Lindahl, Jr. 1981. Host selection behavior of bark beetles (Coleoptera: Scolytidae) attacking *Pinus ponderosa,* with special emphasis on the western pine beetle, *Dendroctonus brevicomis.* J. Chem. Ecol. 7:49-83.

ABSTRACT

Detection of weakened hosts from a distance by bark beetles through olfaction was investigated in field experiments. No significant memebers of Scolytidae were attracted to anaerobically treated pine bolts, stem disks, or sugar and ponderosa pine bark including phloem. Treatment of living trees with cacodylic acid induced attacks by *Dendroctonus brevicomis, D. ponderosae, Ips latidens, Gnathotrichus retusus,* and *Pityophthorus scalptor,* beginning two weeks after treatment. There was no significant difference between landing rates of *D. brevicomis* and *D. ponderosae* on screened treated trees and screened controls. There was a significant increase in landing rates of *G. retusus* and *I. latidens,* because both species had penetrated the screen and produced pheromones. Tree frilling alone did not increase the landing rate of bark beetles. Freezing of the lower trunk with dry ice did not increase significantly the landing rate of *D. brevicomis, D. ponderosae, G. retusus,* or *I. latidens* on screened trees, whereas unscreened frozen trees were attacked by all four species. There was no significantly higher landing rate by *D. brevicomis, D. ponderosae, I.*

Mogren, E. W. 1956. Silvical factors influencing resistance of ponderosa pine in Black Hills beetle attack. Proc. Soc. Am. For., 1955, pp. 61-3.

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Morrow, R. A. 1972. *Dendroctonus ponderosae:* The mountain pine beetle. Colo. State For. Serv., Insect and Dis. Lab., Fort Collins, CO.

Murdock, J., Jr. 1910. A brief history of *Dendroctonus ponderosae* Hopk. in the Black Hills National Forest. 7 pp.

Murray, J. G. 1982. A case study. The mountain pine beetle in the East Kootenays. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/ USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 77-81.

Murtha, P. A. 1986. Interpretation of large-scale colour-IR photographs for bark beetle incipient attack detection. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 65-78.

Myers, C. A. 1974. Multipurpose silviculture in ponderosa pine stands of the Montane Zone of Central Colorado. USDA For. Serv. Res. Pap. RM-132, 15 pp.

Nan Brownell Pirnack. 1979. Front Range Vegetation Management Project - Final Report. Nan Crownell Pirnack NewsSystems, Boulder, Colorado, 24 pp.

Nelson, A. L. and P. P. McCord. 1948. Report of the 1948 Black Hills insect control project. USDA, Bur. Entomol. and Plant Quar., Fort Collins, CO, 18 pp.

Niemann, T. 1986. Cost benefit analysis and other economic decision-making processes in assessing and selecting beetle management options. In Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 128-50.

Nijholt, W. W., L. H. McMullen and L. Safranyik. 1980. Pine oil prevents mountain pine beetle attack on living lodgepole pine trees. Env. Can., Can. For. Serv. Bi-mon. Res. Notes 36:1-2.

ABSTRACT

Pine oil, a by-product of sulphate wood pulping, protected pheromone-baited, living Douglas-fir (*Psuedotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl.), and spruce (*Picea glauca* (Moenen) Voss - *P. engelmannii* Parry hydribds) from attack by Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.), mountain pine beetle (*D. ponderosae* Hopk.), and spruce beetle (*D. rufipennis* (Kirby)), respectively. Pine oil also protected surrounding trees and reduced attack incidence on Douglas-fir, lodgepole pine, and spruce within at least a 10 m radius. $\alpha$-Terpineol, one of the constituents of the pine oil mixture, was less effective.

Nijholt, W. W., L. H. McMullen and L. Safranyik. 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera:Scolytidae). Can. Entomol. 113:337-40.

ABSTRACT

Pine oil, a by-product of sulphate wood pulping, protected pheromone-baited, living Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl.) and spruce (*Picea glauca* (Moench) Voss - *P. engelmannii* Parry hybrids) from attack by Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.), mountain pine beetle (*D. ponderosae* Hopk.), and spruce beetle (*D. rufipennis* (Kirby)), respectively. Pine oil also protected surrounding trees and reduced attack incidence on Douglas-fir, lodgepole pine, and spruce within at least a 10 m radius, a-Terpineol, one of the constituents of the pine oil mixture, was less effective.

Noble, D. 1983. The liquidator of lodgepole pine. USDA For. Serv., For. Res. West, pp. 11-5.

Olson, R. C. 1969. Emergence and attack patterns of *Dendroctonus ponderosae* Hopk. in El Paso County, 1969. Colo. St. For. Serv., 8 pp.

ABSTRACT

The emergence of the Mountain Pine Beetle during August and September was gradual. The majority emerged three weeks after the first flight. Surrounding trees were heavily attacked during this period.

O'Neil, Curtis G. 1983. Mountain pine beetle in lodgepole pine (update)., Roaring Fork and North Fork drainages, Little Snake River, Medicine Bow National Forest, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-83-5, 4 pp.

O'Neil, C. G. 1984. Mountain pine beetle biological evaluation, Mosier Gulch, Clear Creek drainage, BLM, Buffalo, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-84-1, 17 pp.

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O'Neil, C. G. and G. D. Lessard. 1984. Mountain pine beetle in ponderosa pine, Laramie Peak, Medicine Bow National Forest, Wyoming. USDA For. Serv., Rocky Mtn. Reg., Bio. Eval. R2-84-6, 13 pp.

Parker, D. L. 1971. Measuring mountain pine beetle trends and impact on lodgepole pine. USDA For. Serv., Ogden, UT, 4 pp.

Parker, D. L. 1973. Trends of mountain pine beetle outbreaks in mixed stands of preferred hosts. USDA For. Serv., Ogden, UT., 4 pp.

Parker, D. L. 1973. Trend of a mountain pine beetle outbreak. J. For. 71:698-700.

ABSTRACT

Yearly trends of a mountain pine beetle (*Dendroctonus ponderosae* Hopk.) infestation were measured in a 640-acre lodgepole pine (*Pinus contorta* Dougl.) tract in Yellowstone National Park. Before infestation the tract had 211 live trees per acre 5 inches d.b.h. and larger. A seven-year outbreak killed 56 trees per acre, the peak mortality of 27 trees per acre occurring in the fourth year.

* Parker, D. L. 1976. Biological Evaluation. Mountain pine beetle in ponderosa pine. North Kaibab Ranger District, Kaibab National Forest, Arizona, 1975. USDA For. Serv., Southwestern Reg., Rept. No. R3-76-4, 7 pp.

* Parker, D. L. 1977. Biological Evaluation. Mountain pine beetle in ponderosa pine, North Kaibab Ranger District, Kaibab National Forest, Arizona, 1976. USDA For. Serv., Southwestern Reg., Rept. No. R3-77-3, 8 pp.

Parker, D. L. 1978. Detection and evaluation surveys for the mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 125-8.

ABSTRACT

Detection and evaluation surveys are conducted by survey entomologists to gain information for advising resource managers on the need, feasibility and justification for control of damaging insect infestations. This evaluation process involves aerial and ground detection surveys and the following evaluation surveys: estimation of tree damage, determination of the relative abundance of the pest, and estimation of forest susceptibility. The survey techniques commonly used by survey entomologists to detect and evaluate mountain pine beetle (*Dendroctonus ponderosae* Hopkins) infestations are discussed.

Parker, D. L. 1980. Integrated Pest Management Guide. Mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in ponderosa pine, Kaibab Plateau, Arizona. USDA For. Serv., Southwestern Reg., Rept. No. R3 80-8, 12 pp.

* Parker, D. L. and R. E. Acciavatti. 1975. Biological evaluation and damage survey, mountain pine beetle in ponderosa pine, Kaibab Plateau, Kaibab National Forest, Arizona, 1975. USDA For. Serv., Southwestern Reg., Rept. No. R3-75-24, 11 pp.

Parker, D. L. and D. W. Davis. 1971. Feeding habits of *Corticeus substiatus* (Coleoptera: Tenebrionidae) associated with mountain pine beetle in lodgepole pine. Ann. Entomol. Soc. Am. 64:293-4.

Parker, D. L. and R. E. Stevens. 1979. Mountain pine beetle infestation characteristics in ponderosa pine, Kaibab Plateau, Arizona, 1975-1977. USDA For. Serv. Res. Note RM-367, 4 pp.

ABSTRACT

A moderate mountain pine beetle infestation was characterized in standing and downed trees by low attack density, normal egg gallery length, and normal egg numbers. Larger trees produced more brood per unit surface area than smaller trees, and were infested to a greater height. Felled trees were attacked as heavily as standing trees. Trap trees might be used here to augment other beetle management approaches.

Parker, D. L. and L. E. Stipe. 1974. Does the mountain pine beetle select and kill dwarf mistletoe-infected lodgepole pine? USDA For. Serv., Ogden, UT, 5 pp.

* Patterson, J. E. 1927. Progress report of the status of the mountain pine beetle, Season of 1926. Stanford Univ., Palo Alto, CA.

* Patterson, J. E. 1927. Studies of the mountain pine beetle, *Dendroctonus monticolae,* in lodgepole pine infestations, Season of 1927. Stanford Univ., Palo Alto, CA.

* Patterson, J. E. 1928. Studies of the mountain pine beetle in lodgepole pine and other studies conducted in Southern Oregon in 1927. Stanford Univ., Palo Alto, CA.

* Patterson, J. E. 1928. Experiments with the mountain pine beetle in the prevention of attacks and killing of broods. Stanford Univ., Palo Alto, CA.

Patterson, J. E. 1930. Control of the mountain pine beetle in lodgepole pine by the use of solar heat. USDA Tech. Bull. 195, 20 pp.

* Patterson, J. E. 1934. Epidemic of *Dendroctonus monticolae* resulting from broods breeding in sugar pine slash. Big Creek Basin, Stanislaus National Forest, California. USDA Bur. Entomol., Berkeley, CA.

* Patterson, J. E. 1934. Preliminary results of oil treatment of ponderosa pine infested with *D. brevicomis* and of sugar pine infested with *D. monticolae*. EWC field studies, Stanislaus National Forest. USDA Bur. Entomol., Berkeley, CA.

* Peterman, R. M. 1974. Some aspects of the population dynamics of the mountain pine beetle, *Dendroctonus ponderosae,* in lodgepole pine forests of British Columbia. Ph.D. Thesis, Univ. of British Columbia, Vancouver, 208 pp.

Peterman, R. M. 1977. An evaluation of the fungal inoculation method of determining the resistance of lodgepole pine to mountain pine beetle (Coleoptera: Scolytidae) attacks. Can. Entomol. 109:443-8.

ABSTRACT

Field tests were made of the fungal inoculation method of Reid *et al.* which assesses the potential of individual lodgepole pine trees (*Pinus contorta* Dougl. var. *latifolia* Engelm.) to resist

attacks by mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Four hundred and eighty-four trees were inoculated with one of the beetle's mutualistic blue-staining fungi (*Europhium clavigerum* Robinson and Davidson), tree responses were determined, and the potential of each tree to resist *D. ponderosae* was predicted. Two months later, after mountain pine beetles had attacked some of these same trees, most of the predictions based on the fungal assay system proved to be incorrect. Most of the trees which were attacked and which had been rated potentially resistant did not prevent successful bark beetle reproduction. These results, contrary to those of Shrimpton and Reid, suggest that some improvement is needed in the fungal assay method of assessing resistance of lodgepole pine to mountain pine beetle. Measures of tree resistance based on success of mountain pine beetle reproduction showed no difference in the proportion of nonresistant trees between epidemic and endemic areas.

Peterman, R. M. 1978. The ecological role of mountain pine beetle in lodgepole pine forests. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range. Exp. Sta., Univ. of Idaho, Moscow, pp. 16-26.

Pfister, R. D. and D. M. Cole. 1985. The host. In M. D. McGregor and D. M. Cole (eds.). Integrating management strategies for the mountain pine beetle with multiple-resource management of lodgepole pine forests. USDA For. Serv. Gen. Tech. Rept. INT-174, pp. 7-28.

* Pitman, G. B. 1969. Bark beetle manipulation with natural and synthetic attractants. In Insect plant interactions, Nat. Acad. Sci., Wash., DC pp. 56-8.

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ABSTRACT

Synthetic *trans*-verbenol containing 6% *cis*-verbenol and 1% unknowns combined with alpha-pinene was highly attractive to in-flight mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Alpha-pinene was the most active of the terpenes tested with *trans*-

verbenol. Myrcene showed intermediate activity, while limonene and 3-carene apparently were ineffective in eliciting a response. As behavior-regulating chemicals, *trans*-verbenol and alpha-pinene were effective in manipulating the host selection patterns of *D. ponderosae*. When 725 mature white pines, distributed over eight 40-acre plots in northern Idaho, were baited with the 2 materials, 133 or 18% were attacked heavily and subsequently killed. Beetle attacks were noted on an additional 13% of the baited trees, but these were aborted without tree mortality. Prior to baiting, all trees were sprayed to a height of about 20 ft. with a 2.3% solution of lindane. The mortality of sprayed trees suggested that lindane was not effective under the conditions of this study. Only 21 of the estimated 7200 unbaited mature pines within the boundaries of the study plots were mass attacked, and 11 of these trees were within 10 to 15 ft of baited mass-attacked trees.

Paperboard cylinders, about 2 ft x 10 in., covered with a tacky substance and baited with *trans*-verbenol and alpha-pinene appeared effective as a means of deadtrapping *D. ponderosae*. An abnormally high attack density could not be induced on a white pine baited with a massive amount of *trans*-verbenol and alpha-pinene.

Pitman, G. B., M. W. Stock and R. C. McKnight. 1978. Pheromone application in mountain pine beetle/lodgepole pine management: Theory and practice. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 165-73.

ABSTRACT

This report reviews two uses of pheromones to effect bark beetle population changes, mass trapping and protection of susceptible host trees by disruption of host selection and colonization. A number of theoretical tactics using pheromones for suppression and protection of lodgepole pine against the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) are discussed. From these tactics, application of the aggregative pheromone pondelure to high-risk trees scheduled for harvest is presently feasible. Current limitations to employing pheromones in mountain pine beetle/lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) management programs are attributed to large areas of undermanaged lodgepole pine, the high and extensive level of present mountain pine beetle epidemics, and the need for more research to identify and evaluate additional behavior regulators functioning in the pest's chemical communication system. Recent research, however, has clearly demonstrated the high potential for pheromone use in mountain pine beetle control programs.

Pitman, G. B. and J. P. Vitè. 1969. Aggregation behavior of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) in response to chemical messengers. Can. Entomol. 101:143-9.

ABSTRACT

Populations of *Dendroctonus ponderosae* Hopk. aggregate on pine trees in response to a combination of host- and insect-produced volatiles. Release of the insect-generated volatiles by defecation coincides with the release of host volatiles as resin exudes from the galleries initiated by the female beetle. When tested with oleoresin under field conditions, synthetic *trans*-verbenol, the major insect pheromone, was highly attractive to both sexes of *D. ponderosae*. Also, emergent female *Dendroctonus brevicomis* Lee. and *Dendroctonus frontalis* Zimm. crushed to powder at -70°C were attractive; emergent females of both species are known to contain large amounts of *trans*-verbenol. *Trans*-verbenol *per se*, however, was not attractive to walking or flying *D. ponderosae*.

Pitman, G. B., J. P. Vitè, G. W. Kinzer and A. F. Fentiman, Jr. 1968. Bark beetle attractants: *Trans*-verbenol isolated from *Dendroctonus*. Nature 218:168-9.

Pitman, G. B., J. P. Vite, G. W. Kinzer and A. F. Fentiman, Jr. 1969. Specificity of population-aggregating pheromones in *Dendroctonus*. J. Insect Physiol. 15:363-6.

ABSTRACT

In *Dendroctonus* the production of population-aggregating pheromones is not specific to sex or species. Aggregation is largely maintained by the specificity of olfactory receptor systems.

Pollack, R. and J. Pollock. 1977. The pine killer. Colo. Outdoors. 26:41-4.

Powell, J. M. 1961. The mountain pine beetle, *Dendroctonus monticolae* Hopk. in Western Canada. Can. Dept. Agr., For. Entomol. and Pathol. Br., Calgary, Alberta, Int. Rept. May.

Powell, J. M. 1966. Distributions and outbreaks of *Dendroctonus ponderosae* Hopk. in forests of Western Canada. Dept. of For., For. Res. Lab., Calgary, Alberta, Inform. Rept. A-X-2, 19 pp.

Powell, J. M. 1967. A study of habitat temperatures of the bark beetle *Dendroctonus ponderosae* Hopkins in lodgepole pine. Agr. Met. 4:189-201.

ABSTRACT

Temperatures were measured at the bark surface and in the subcortical zone of *Pinus contorta* Douglas var. *latifolia* Engelm. infested by *Dendroctonus ponderosae* Hopkins and compared with similar measurements in non-infested trees and with air temperatures. Subcortical temperatures were higher at night but usually lower during the day than air temperatures. Surface bark temperatures were intermediate. Temperatures were lower at the 1-ft level than at higher levels. Highest subcortical temperatures occurred on the south aspect; daily maxima were later in the day and daily range was greater in infested than in non-infested trees, especially during the late stages of beetle brood development. Thin-bark trees had higher temperatures and less temperature lag than thick-bark trees. Temperatures were 5.5 to 7.5°C higher under maritime tropical than maritime polar air. The effects of temperature on various aspects of beetle behavior, development and survival are discussed. Approximately 8,340 degree-hours above 10°C were required in the subcortical zone for the beetle to develop from egg to teneral adult.

Powell, J. M. 1969. Historical study of the relation of major mountain pine beetle outbreaks in Western Canada to seasonal weather. Can. For. Serv., For. Res. Lab., Calgary, Alberta, Inform. Rept. A-X-23, 11 pp.

Quenet, R. V. 1986. Integration of pest damage data into the British Columbia Forest Service inventory data base. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 61-4.

Raffa, K. F. and A. A. Berryman. 1980. Flight responses and host selection by bark beetles. In A. A. Berryman and L. Safranyik (eds.). Proc. 2nd IUFRO Conf. on dispersal of forest insects: evaluation, theory and management implications. Wash. St. Univ. Coop. Ext. Serv., Pullman, Wash., pp. 213-33.

Raffa, K. F. and A. A. Berryman. 1982. Gustatory cues in the orientation of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) to host trees. Can. Entomol. 114:97-104.

ABSTRACT

Female mountain pine beetles, *Dendroctonus ponderosae* Hopkins, were exposed to papers soaked in outer bark extracts of lodgepole pine, *Pinus contorta* Douglas var. *latifolia* Engelmann. Both benzene and methanol-water extracts elicited greater feeding activity than did controls. Non-polar host compounds exhibited greater incitant (initiation of feeding) properties, while polar compounds were more powerful stimulants (continuation of feeding). No differences were detected in feeding on extracts from resistant or susceptible trees. Repellency appears to be associated with beetle responses to active host metabolism.

Raffa, K. F. and A. A. Berryman. 1982. Physiological differences between lodgepole pines resistant and susceptible to the mountain pine beetle and associated microorganisms. Env. Entomol. 11:486-92.

ABSTRACT

Lodgpeole pines, *Pinus contorta* Douglas var. *latifolia* Engelmann, were assayed for traits associated with resistance to the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). There was no relationship between resistance and the daily rate of resin flow, rate of resin crystallization, monoterpene content, monoterpene composition, or current growth rate. The major difference between trees which survived or died during exposure to naturally occurring high beetle populations was the extent of their active response to fungal invasion. Resistant trees responded to artifical inoculation with fungi vectored by *D. ponderosae* by forming greater quantities of resin than did susceptible trees. This wound response is general in nature, quantitatively variable, metabolically active, rapid, and localized. It appears to form the major line of defense to *D. ponderosae* and its associated fungi, and to be related to the general vigor of the tree. The wound response was greatest in those trees which had a periodic growth ratio greater than unity.

Raffa, K. F. and A. A. Berryman. 1983. Physiological aspects of lodgepole pine wound responses to a fungal symbiont of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera:Scolytidae). Can. Entomol. 115:723-34.

ABSTRACT

The acetone-soluble fraction of phloem tissue samples from 78 lodgepole pines was examined prior to and following artical inoculation with *Europium clavigerum*, a fungus transmitted by the mountain pine beetle.

All trees showed quantitative increases in the concentration of extractives within 3 days after treatment. Further increases continued for at least 7 days. By this time qualitative changes in the chemical composition of the host tissue had also occurred.

Trees were defined as resistant or susceptible depending on whether they survived beetle attack under natural conditions. The composition of the acetone-soluble extracts was similar for the constitutive tissue of resistant and susceptible trees, but the total quantity of acetone extractives of reaction tissue was higher in resistant trees.

The ability of trees to respond to fungal inoculation is diminished by mass attack. Trees responded more extensively to inoculation prior to, than during, aggregation under field conditions. An experiment was conducted to simulate this relationship under controlled conditions by examining the effect of multiple fungal inoculations on the production of monoterpenes during the wound response. Individual trees showed a weaker quantitative response on stem sections administered high inoculation densities than on stem sections administered only a single inoculation. Those trees which responded most extensively to a single invasion by the pathogen were more responsive at all inoculum densities.

* Raffa, K. F. and A. A. Berryman. 1983. The role of host plant resistance in the colonization behavior and ecology of bark beetles. Ecol. Monogr. 53:27-49.

Raimo, B. J. and D. M. Haneman. 1981. An evaluation to determine the susceptibility of lodgepole pine to mountain pine beetle infestation in the Dunoir Special Management Unit. USDA For. Serv., Rocky Mtn. Reg., Rept. No. R2-81-6, 5 pp.

Rasmussen, L. A. 1972. Attraction of mountain pine beetles to small-diameter lodgepole pines baited with *trans*-verbenol and alpha-pinene. J. Econ. Entomol. 65:1396-9.

ABSTRACT

Lodgepole pines, *Pinus contorta* Douglas, 8.9 in. diameter at breast height (DBH) or less, were baited with the pheromone *trans*-verbenol and the terpene alpha-pinene to determine if populations of *Dendroctonus ponderosae* Hopkins could be attracted to these trees of small diameter. Even though the beetles in most cases did not successfully attack baited trees, such trees were usually the first to be attacked. This phenomenon indicated that these

chemicals might be used to attract beetles into areas with baited trees but not in baited trees exclusively. This indication was supported by the fact that the beetles successfully attacked larger unbaited trees.

Rasmussen, L. A. 1974. Flight and attack behavior of mountain pine beetles in lodgepole pine of Northern Utah and Southern Idaho. USDA For. Serv. Res. Note INT-180, 7 pp.

ABSTRACT

Temperature appears to be the most important factor influencing flight and attack behavior of the mountain pine beetle *(Dendroctonus ponderosae* Hopk.). To a large extent, temperature governs onset, daily time and length of emergence and flight, and location of initial attack. The optimum temperature range for adult mountain pine beetle activity extends from about 19°C to about 32°C; higher or lower temperatures limit beetle activity. Even though the sex ratio of attacking beetles favored the female in this study, all females were mated within at least 10 days of a mass attack on lodgepole pine *(Pinus contorta* Dougl.). Mated females constructed galleries at a greater rate than unmated females.

Rasmussen, L. A. 1976. Keys to common parasites and predators of the mountain pine beetle. UDA For. Serv. Gen. Tech. Rept. INT-29, 4 pp.

Rasmussen, L. A. 1980. Emergence and attack behavior of the mountain pine beetle in lodgepole pine. USDA For. Serv. Res. Note INT-297, 7 pp.

ABSTRACT

Factors influencing the behavior of mountain pine beetles infesting lodgepole pine were studied during 1974 and 1975. More and larger beetles emerged from trees having thickest phloem, with the largest beetles usually emerging first. Beetles emerging in 1974 constructed more gallery and laid more eggs than did beetles emerging in 1975, probably due to the late beetle flight in 1975 and larger size of the females. Trees that were successfully mass attacked had lower inner bark temperatures than trees unsuccessfully attacked. The sex ratio of emerging beetles was 1.52:1, females to males; for attacking beetles it was about the same, 1.50:1, but for the boring beetles it was 2.34:1.

Reid, R. W. 1955. The bark beetle complex associated with lodgepole pine slash in Alberta. I. Notes on the biologies of some Scolytidae attacking lodgepole pine slash. Can. Entomol. 87:311-23.

* Reid, R. W. 1956. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk. Interim Rep. 1955-1. For. Biol. Lab., Calgary, Alberta.

* Reid, R. W. 1957. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk. Interim Rep. 1956-9. For. Biol. Lab., Calgary, Alberta.

Reid, R. W. 1957. The bark beetle complex associated with lodgepole pine slash in Alberta. Pt. II. Notes on the biologies of several parasites. Can. Entomol. 89:5-8.

Reid, R. W. 1957. The bark beetle complex associated with lodgepole pine slash in Alberta. Pt. III. Notes on the biologies of several predators with special reference to *Enoclerus sphegeus* Fab. (Coleoptera: Cleridae) and two species of mites. Can. Entomol. 89:111-20.

Reid, R. W. 1957. The bark beetle complex associated with lodgpeole pine slash in Alberta. Pt. IV. Distribution, population densities and effects of several environmental factors. Can. Entomol. 89:437-47.

Reid, R. W. 1958. Studies on the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk. Interim Rep. 1957-4. For. Biol. Lab., Calgary, Alberta.

Reid, R. W. 1958. Internal changes in female mountain pine beetle, *Dendroctonus monticolae* Hopk., associated with egg laying and flight. Can. Entomol. 90:464-8.

Reid, R. W. 1958. The behavior of the mountain pine beetle, *Dendroctonus monticolae* Hopk., during mating, egg laying, and gallery construction. Can. Entomol. 90:505-9.

* Reid, R. W. 1958. Nematodes associated with the mountain pine beetle. Can. Dept. of Agri., For. Biol. Env. Bimonthly Prog. Rept. 14:3

* Reid, R. W. 1960. Studies of the biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins (Coleoptera: Scolytidae). Ph.D. thesis, Montana State Col., Bozeman.

Reid, R. W. 1961. Moisture changes in lodgepole pine before and after attacks by the mountain pine beetle. For. Chron. 37:368-75.

ABSTRACT

The moisture content of the outer sapwood of non-infested lodgepole pine is normally about 85 to 165 per cent of oven dry weight. In trees that have been infested by the mountain pine beetle for one year, the sapwood moisture content can be as low as 16 per cent. There is a steep moisture gradient from about 160 per cent in the outer sapwood to about 30 per cent in the heartwood. The moisture content in the centre is slightly higher than in the adjacent wood. In infested trees the sapwood moisture is greatly reduced within a year after the attack but moisture in the heartwood is not altered appreciably. Trees infested early in the season drop to a lower moisture content by fall than trees infested later in the season. In non-infested trees there is a diurnal and a seasonal moisture march; these do not occur in infested trees. The rapid moisture loss in the sapwood of infested trees is associated with blue-stain infection and successful establishment of bark beetle broods.

Reid, R. W. 1962. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopk., in the East Kootenay Region of British Columbia. I. Life cycle, brood development, and flight periods. Can. Entomol. 94: 531-8.

Reid, R. W. 1962. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the east Kootanay Region of British Columbia. II. Behavior in the host, feundity, and internal changes in the female. Can. Entomol. 94:605-13.

Reid, R. W. 1963. Biology of the mountain pine beetle, *Dendroctonus monticolae* Hopkins, in the East Kootenay Region of British Columbia. III. Interaction between the beetle and its host, with emphasis on brood mortality and survival. Can. Entomol. 95:225-38.

ABSTRACT

Studies were made on the distribution and survival of the mountain pine beetle over the lower stem of lodgepole pine. The relationship between density of attack and subsequent total length of egg galleries was examined as was the relationship between number of exit holes and number of emerging beetles. The influence on brood survival of tree diameter, density of egg galleries, moisture content of the outer sapwood, lethal temperatures, resinosis in the subcortical region, predators, and parasites is described. Survival is compared between broods established during different flights in the same year. The optimum weather conditions for brood survival are discussed.

Reid, R. W. 1969. The influence of humidity on incubating bark beetle eggs. Can. Entomol. 101:182-3.

Reid, R. W. and H. S. Gates. 1970. Effects of temperature and resin on hatch of eggs of the mountain pine beetle *(Dendroctonus ponderosae)* Can. Entomol. 102:617-22.

ABSTRACT

Effects of temperature and resin on hatch of mountain pine beetle eggs were investigated. Per-cent hatch was related to total degree-hours above 40°F, the average being 5113 for 50% hatch under field conditions. Average supercooling point was 1.3°F. Higher temperatures in the freezing range were lethal with long exposure. Atmosphere saturated with volatiles from liquid resin had very little effect on egg hatch, but direct contract with liquid resin greatly reduced egg hatch.

Reid, R. W. and H. S. Gates. 1972. Relations between some physiological functions in lodgepole pine and resistance to the mountain pine beetle. Env. Can., Can. For. Serv., Northern For. Res. Cent. Inf. Rept. NOR-X-15.

ABSTRACT

Stands of lodgepole pine exhibited varying degrees of resistance to attack by the mountain pine beetle. Variations in water tension within individual trees were reflected directly in circumference expansion and contraction, particularly following periods of stress, and this characteristic was related to some extent with the incidence of successful insect attack. Growth rhythms in the tree stems were not detected and degree of starch accumulation in the bole did not appear related to the degree of tree resistance.

Reid, R. W., H. S. Whitney and J. A. Watson. 1967. Reaction of lodgepole pine to attack by *Dendroctonus ponderosae* Hopkins and blue stain fungi. Can. J. Bot. 45:1115-26.

ABSTRACT

The reaction in lodgepole pine in response to attack by *Dendroctonus ponderosae* and subsequent infection by blue stain fungi varies with the degree of resistance manifested by the tree. In both resistant and successfully attacked trees a sequence of changes, which increase in space with time, occurs in the inner bark and sapwood. In resistant trees a condition termed secondary resinosis develops which is lethal to bark beetle broods and blue stain fungi. In contrast, successfully infested trees do not exhibit secondary resinosis, and bark beetle broods and blue stain fungi survive and complete their development. In resistant trees blue stain fungi are responsible, directly or indirectly, for the extensive reaction and condition of secondary resinosis which is associated with the insect gallery. Changes in stem tissues associated with wounding are discussed.

* Renwick, J. A. A. and J. P. Vitè. 1970. Systems of chemical communication in *Dendroctonus*. Contr. Boyce Thompson Inst. 24:283-92.

* Richmond, H. A. 1931. Annual report of investigations of *Dendroctonus monticolae* Hopkins; yellow pine and lodgepole pine stands, Aspen Grove, B.C. and population and life history studies, damage and tree mortality, parasites and predators, host selection. For. Biol. Lab., Vernon, B.C.

Richmond, H. A. 1933. Host selection studies of *Dendroctonus monticolae* Hopkins in southern British Columbia. For. Chron. 9:60-1

* Richmond, H. A. 1934. Summary of season's work, Aspen Grove project. For. Biol. Lab., Vernon, B.C.

* Richmond, H. A. 1935. Studies on the mountain pine beetle, Ann. Rept. For. Entomol. Lab., Vernon, B.C.

* Richmond, H. A. 1935. A morphological study of the bark beetle *Dendroctonus monticolae* Hopk. M.S. Thesis, McGill Univ., Montreal, Quebec.

Robertson, J. 1979. The mountain pine beetle - friend or foe? Am. For. 85:38-43.

Robinson, R. C. 1962. Blue stain fungi in lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) infested by the mountain pine beetle (*Dendroctonus monticolae* Hopk.) Can. J. Bot. 40:609-14.

ABSTRACT

A complex of fungi was isolated from lodgepole pine *(Pinus contorta* Dougl. var. *latifolia* Engelm.) at various stages of mountain pine beetle *(Dendroctonus monticolae* Hopk.) attack. *Ceratocystis montia* Rumb., *Leptographium* sp., *Pichia pini* (Holst) Phaff, *Hansenula holstii* Wickerham, *Hansenula capsulata* Wickerham, and some unnamed yeasts were isolated from beetles, fresh galleries, and blue-stained sapwood. Perithecia of *C. montia, Ceratocystis minor* (Hedge.) Hunt, *Ceratocystis minuta* (Siem.) Hunt, *Ceratocystis* sp., and *Europhium* sp. were found on the bark and sapwood of dead, blue-stained trees. Beetles are conclusively shown to be vectors of blue stain fungi. The known ranges of *C. montia* and *P. pini* are extended by this study and a possible succession of organisms associated with the development of beetle infestation is discussed.

Roe, A. L. and G. D. Amman. 1970. The mountain pine beetle in lodgepole pine forests. USDA For. Serv. Res. Paper INT-71, 23 pp.

ABSTRACT

The mountain pine beetle depletes Rocky Mountain lodgepole pine stands by removing periodically the largest, most vigorous trees. Some stands are replaced by succeeding species in 80 to 100 years.

Intensities of mountain pine beetle and dwarf mistletoe damage are influenced by forest associations and elevation. Dwarf mistletoe infection reduced phloem depth and probably results in lower mountain pine beetle brood production.

The probability of lodgepole pine surviving to 16 inches d.b.h. is about two out of three in the *Abies lasiocarpa/Vaccinium scoparium* association, but only one out of four in the *Abies lasiocarpa/Pachistima myrsinites* association. The latter association offers the greatest risk to lodgepole pine. More effective beetle control and alternatives such as type conversion, shorter rotations, mixing species, and developing better size and age class distribution must be considered.

* Ross, D. A. 1957. A preliminary report on appraisal of the amount of timber killed by bark beetles of the genus *Dendroctonus*. Interior B.C. Can. Dept. Agr., For. Biol. Lab., Vernon, B.C., Int. Rept. 1956-2.

Ross, D. A. 1965. Control of mountain pine beetle, *Dendroctonus ponderosae* Hopk., brood in logs with lindane emulsion. Proc. Entomol. Soc. B.C. 62:8-10.

Rost, M. T. 1978. Comments on the mountain pine beetle/lodgepole pine symposium. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 205-7.

ABSTRACT

The questions of what managers need from researchers and the extent to which this symposium met that need are discussed. The importance of preventive programs is emphasized. Ways in which

managers can become more involved in solving the problem of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) in lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelmann) are suggested.

Rudinsky, J. A. and R. R. Michael. 1973. Sound production in Scolytidae: stridulation by female *Dendroctonus* beetles. J. Insect Physiol. 19: 689-705.

Rudinsky, J. A., M. E. Morgan, L. M. Libbey, and T. B. Putnam. 1974. Antiaggregative-rivalry pheromone of the mountain pine beetle, and a new arrestant of the southern pine beetle. Env. Entomol. 3:90-8.

ABSTRACT

Eight pheromones were collected as volatiles from living *Dendroctonus* beetles, and identified by GLC/MS. With *Dendroctonus frontalis* Zimmerman, in addition to earlier reported pheromones, the monoterpene ketone pinocarvone, and frontalin, were released by males, and the terpene alcohol myrtenol was released by both males and females. With *D. ponderosae* Hopkins, besides the previously known pheromones, *endo*-brevicomin and 3-methyl-2-cyclohexen-1-one (MCH) were released by males, and frontalin was collected from pairs of this species. Bioassay indicated that *exo*-brevicomin with *D. ponderosae,* and myrtenol as well as verbenone with *D. frontalis,* are multifunctional pheromones, since a small quantity (released by females) was synergistically attractive, and a larger quantity (released by males) was pressive and/or evoked "rivalry" behavior. For this latter effect, the male pheromones were designated antiaggregative-this species releases no inhibitor and depends upon host oleoresin effects to stop beetle aggregation. The identified male pheromones were released with males placed together, as well as with pairs, and the pheromones of female *D. frontalis* (though not of female *D. ponderosae)* were also released with females placed together, as well as with pairs. Both intrasex and intersex stimuli and response must be important in pheromone release, and may help answer certain questions about bark beetle behavior of practical significance in attempts to utilize these pheromones in control.

Rumbold, C. T. 1941. A blue stain fungus *Ceratostomella montium* n. sp. and some yeasts associated with two species of *Dendroctonus*. J. Agr. Res. 62:589-601.

* Rust, H. J. 1929. Preliminary Report on the effectiveness of the peeling method of control relative to the destruction of *Dendroctonus* broods. USDA Bur. Entomol., Coeur d'Alene, ID.

* Rust, H. J. 1929. Relation of insectivorous birds to the mortality of the mountain pine beetle during flight period. UDSA Bur. Entomol., Coeur d'lene, ID.

* Rust, H. J. 1930. Relation of insectivorous birds to mortality of the mountain pine beetle during flight period. USDA Bur. Entomol. Coeur d'Alene, ID.

* Rust, H. J. 1931. Final report on the role of ants, centipedes, and rodents destructive to broods of the mountain pine beetle exposed by the peeling method of control. USDA Bur. Entomol., Coeur d'Alene, ID.

* Rust, H. J. 1933. Many bark beetles destroyed by predacious mites. J. Econ. Entomol. 26:773-4

Rust, H. J. 1935. The role of predatory agents in the artificial control of the mountain pine beetle. J. Econ. Entomol. 28:688-91.

Ryker, L. C. and J. A. Rudinsky. 1976. Sound production in scolytidae: Aggressive and mating behavior of the mountain pine beetle. Ann. Entomol. Soc. Am. 69:677-80.

ABSTRACT

*Dendroctonus ponderosae* Hopkins males emitted interrupted chirps both while fighting a rival male and when attracted into a virgin female's gallery. Behavior accompanying interrupted chirps was aggressive in both contests. Females became silent and permitted entry when chirping males touched them, but chirped continuously, attacked, and usually ejected surgically silenced males, indicating a premating recognition function for the interrupted chirp nonaggressive, courting behavior occurred in the

gallery as stridulation changed to simple, uninterrupted chirps just before mating. Females responded to stridulation at the gallery entrance by simple, multi-impulse chirps similar to the territorial chirp reported earlier. The chirp is not emitted during courtship and appears be mainly a territorial response to intruders. Phonostimulus of acoustic response between the 2 sexes, in addition to the previously shown olfactory response, is now established.

Ryker, L. C. and L. M. Libbey. 1983. Frontalin in the male mountain pine beetle. J. Chem. Ecol. 8:1399-1409.

ABSTRACT

Frontalin and *exo*-brevicomin were identified by GC-MS in air drawn over male *Dendroctonus ponderosae* Hopk. (MPB) from Oregon that had joined females for 1-2 days in the bark of lodgepole pine and ponderosa pine logs. Unfed males released *exo*- and *endo*-brevicomin but not frontalin. Arrestment of males by *trans*-verbenol and terpenes in an olfactory walkway was reduced by the addition of racemic frontalin; production of attractant chirps also diminished. Racemic frontalin also strongly reduced the aggregation of MPB in lodgepole and ponderosa pine stands to sticky traps baited with the aggregation pheromone *trans*-verbenol and host terpenes; however, the function of the natural enantiomer of frontalin in MPB is unknown.

* Safranyik, L. 1968. Development of a technique for sampling mountain pine beetle populations in lodgpeole pine. Ph.D. Thesis, Univ. of B.C., Vancouver, 195 pp.

Safranyik, L. 1971. Some characteristics of the spacial arrangement of attacks by the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), on lodgepole pine. Can. Entomol. 103:1607-25.

ABSTRACT

Evidence is given in support of the hypothesis that the spatial arrangement of attacks by the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) on its host, lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), is largely determined by the pattern of bark niches suitable for attack initiation. Density of attack sites and bark thickness are important to determine the attack-harbouring potential of the bark and in determining the upper limit of attacks, thus, the potential area available for

attack on the bark surface of lodgepole pine trees. At fixed levels on the clear bole of naturally infested trees, attack pattern tends to be regular owing to the regular spatial pattern of suitable attack sites. The regularity of the attack pattern is disturbed by the presence of an attack-density gradient around the stem circumference. The vertical attack-density gradient over the host is well described in terms of a relation between attack density and bark thickness. This relation is asymptotic and rests on the assumption that the density of bark niches suitable for attack initiation approaches an upper limit with increasing bark thickness on lodgepole pine trees.

Safranyik, L. 1976. Size- and sex-related emergence, and survival in cold storage, of mountain pine beetle adults. Can. Entomol. 108:209-12.

ABSTRACT

Larvae of the mountain pine beetle, *Dendroctonus ponderosae* Hopk., were reared to adults in naturally infested bolts of lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm., at 21 $\pm$ 3°C. The mean pronotal width of the emerging beetles of both sexes decreased, and the male:female ratio increased, during the emergence period. On the average, larger individuals of both sexes survived longer when adult beetles were stored at 1 $\pm$ 2°C. Also, the male:female ratio of the survivng beetles decreased with increased storage duration. These and related results in the literature suggest that in natural populations of the mountain pine beetle average adult size increases, and the male:female ratio decreases, following stress-induced mortality in the larval and(or) adult stages.

* Safranyik, L. 1976. Climatic barriers and influences on integrated control of *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae) in western Canada. In R. Z. Callaham and A. Bakke (eds.). Proc. XVI IUFRO Conf. Oslo, Norway.

Safranyik, L. 1978. Effects of climate and weather on mountain pine beetle populations. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range. Exp. Sta., Univ. of Idaho, Moscow, pp. 77-84.

ABSTRACT

The literature on the direct effects of climate and weather on the biology and dynamics of mountain pine beetle *(Dendroctonus ponderosae* Hopkins) populations is reviewed and discussed, with emphasis on the development of epidemics. Of the climatic effects, temperature is the most important. Typically, in the optimum range of the beetle's distribution on lodgepole pine *(Pinus contorta* Douglas var. *latifolia* Engelmann), there is enough heat accumulation each year to produce one or more generations and the frequency of adverse weather conditions is not high enough to prevent population build-up or to reduce infestations to endemic levels. In some years, however, adverse weather can cause a decline in population and damage levels, but this reversal is usually temporary and the course of outbreak is largely determined by factors other than climate. In this optimum habitat, the beetle poses a continuous threat to lodgepole pine of susceptible age and size. At high elevation and at northern latitudes, climate becomes the dominant factor controlling the distribution and abundance of mountain pine beetle populations and infestations in space and time. Beetle development is out of phase with the cold season; consequently, the least cold-hardy life stages (eggs, pupae) may enter the winter and suffer heavy mortality. Epidemics tend to be less frequent and intense, and stand depletion decreases, toward the limits of the distributional range. The northern limit of the beetle's range is bounded by the isotherm for -40°C (-40°F) mean annual minimum temperature and a zone where, on the average, heat accumulation during the growing season is less than the estimated minimum (833 degree-days C) for brood development on a 1-year cycle. The upper altitudinal limit, which ranges from about 750 m (2460 ft) near the northern limit (latitude 56°N) to about 3650 m (11,972 ft) near the southern limit (latitude 31°N), is probably delimited by similar temperature conditions.

* Safranyik, L. 1981. Population biology and management in lodgepole pine. In Mountain pine beetle symposium, Coleman, Alberta, pp. 80-5.

Safranyik, L. 1982. Alternative solutions. Preventative management and direct control. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 29-32.

Safranyik, L. 1983. The role of the host in population dynamics of forest insects. Proc. of IUFRO Conf., Banff, Alberta, Can.

Safranyik, L. 1986. Effect of climatic factors on development, survival, and life cycle of the mountain pine beetle. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 14-24.

Safranyik, L. 1986. Application and feasibility of alternate control strategies. In Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 104-11.

Safranyik, L. and R. Jahren. 1970. Emergence patterns of the mountain pine beetle from lodgepole pine. Dept. Fish. For., Bimonthly Res. Notes 26:11-19.

Safranyik, L. and R. Jahren. 1970. Host characteristics, brood density and size of mountain pine beetles emerging from lodgepole pine. Dept. Fish. For. Can., Bimonthly Res. Notes 26:35-6.

* Safranyik, L. and D. A. Linton. 1982. Survival and development of mountain pine beetle broods in jack pine bolts from Ontario. Can. For. Serv. Res. Notes 2:17-8.

* Safranyik, L. and D. A. Linton. 1983. Brood production by three species of *Dendroctonus* (Coleoptera: Scolytidae) in bolts from host and non-host trees. J. Entomol. Soc. B. C. 80:10-3.

ABSTRACT

Brood establishment and production by mountain pine beetles, Douglas-fir beetles, and spruce beetles were investigated in the laboratory, in 40 cm bolts of subalpine fir, spruce (*Picea glauca* x *P. engelmannii* hybrid, lodgepole pine and Douglas-fir. In subalpine fir, a few eggs were laid by mountain pine and spruce and Douglas-fir beetles but no brood matured. Production of egg galleries by spruce beetles in this host was the same as it was in spruce, its principal host. In Douglas-fir, eggs were produced only by Douglas-fir beetles and the production of galleries by this bark beetle was significantly greater than that by either of the other beetles. All three beetle spp. produced mature broods in lodgepole pine and in spruce.

* Safranyik, L. and D. A. Linton. 1985. The relationship between density of emerged *Dendroctonus ponderosae* (Coleoptera: Scolytidae) and density of exit holes in lodgepole pine. Can. Entomol. 117:267-75

* Safranyik, L., D. M. Shrimpton and H. S. Whitney. 1974. Management of lodgepole pine to reduce losses from mountain pine beetle. Can. For. Serv., For. Tech. Rept. 1, 24 pp.

Safranyik, L., D. M. Shrimpton and H. S. Whitney. 1975. Mountain pine beetle bibliography. Env. Canada, Forestry Serv., Pac. For. Res. Cent. Rept. BC-X-126, 69 pp.

Safranyik, L., D. M. Shrimpton and H. S. Whitney. 1975. Mountain pine beetle workshops. Planning and execution. Env. Canada, For. Serv., Pac. For. Res. Cent.:BC-P-15, 42 pp.

* Safranyik, L., D. M. Shrimptom and H. S. Whitney. 1975. An interpretation of the interaction between lodgepole pine, the mountain pine beetle and its associated blue stain fungi in western Canada. In D. M. Baumgartner (ed.). Management of lodgepole pine ecosystems, Wash. St. Univ. Coop. Ext. Serv., Vol. 1, pp. 406-28.

Safranyik, L., G. A. VanSickle, and G. H. Manning. 1981. Position paper on mountain pine beetle problems with special reference to the Rocky Mountain Parks Region. Env. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, B.C., 27 pp.

* Safranyik, L. and H. S. Whitney. 1980. Using explosives to destroy mountain pine beetle broods in lodgepole pine trees. J. Entomol. Soc. B. C. 77:3-15.

* Safranyik, L. and H. S. Whitney. 1985. Development and survival of axenically reared mountain pine beetles, *Dendroctonus ponderosae* (Coleoptera: Scolytidae), at constant temperatures. Can. Entomol. 117:185-92.

* Salman, K. A. 1933. Further tests of oil spray to control the western and mountain pine beetles. USDA Bur. Entomol., Berkeley, CA

* Salman, K. A. 1935. The composition of forest insect infestations in ponderosa pine as determined by stem analysis. USDA Bur. Entomol., Berkeley, CA

Salman, K. A. 1938. Recent experiments with penetrating oil sprays for the control of bark beetles. J. Econ. Entomol. 31:119-23.

Salman, K. A. and J. W. Bongberg. 1942. Logging high-risk trees to control insects in the pine stands of Northeastern California. J. For. 40:533-9

ABSTRACT

The problem of pine beetle control in ponderosa pine has been studied by the Bureau of Entomology and Plant Quarantine for more than thirty years. The first method of control, proposed by Hopkins in 1909 consisted of reducing bark beetle populations by felling, peeling, and burning infested trees or removing them to mills. This method of control is still in use under certain conditions, but like other methods of direct control it produces only temporary results. Consequently, members in the Bureau of Entomology and Plant Quarantine for many years have been attempting to devise certain indirect methods to reduce losses from pine beetles. One of these indirect methods is logging high-risk trees which in the pine stands of northeastern California has given encouraging results.

Sampson, G. R., D. R. Betters, and R. W. Brenner. 1980. Mountain pine beetle, timber management and timber industry in Colorado's Front Range: production and marketing alternatives. USDA For. Serv. Res. Bull. RM-3, 8 pp.

ABSTRACT

Current harvest levels and processing capacity do not take full advantage of timber potentially available in six Front Range timbersheds. Four alternatives for utilizing this resource were analyzed using a goal programming technique. Multiproduct operations based on numerous small sawmills appear to offer the best solution.

Sampson, G. R., D. R. Betters, and R. R. Love. 1980. Insect-infected ponderosa pine and associated timber potentially available at six Colorado centers. USDA For. Serv. Res. Bull. RM-1, 6 pp.

ABSTRACT

Increased timber harvesting by forest industry, resulting in more intensive forest management, would be a means for combating insect problems such as the current mountain pine beetle outbreak. However, existing timber processing capability is far less than potential annual harvest of live timber for Colorado's Front Range.

Sartwell, C. 1969. Role of mountain pine beetle in the population ecology of ponderosa pine. Bull. Oregon. Entomol. Soc. 35:255.

Sartwell, C. 1971. Thinning ponderosa pine to prevent outbreaks of mountain pine beetle. In D. M. Baumgartner (ed.). Precommercial thinning of coastal and intermountain forests in the Pacific Northwest. Wash. St. Univ., Coop. Ext. Serv., Pullman, pp. 41-52.

ABSTRACT

Severe tree killing by *Dendroctonus ponderosae* is an increasing pest problem in second-growth *Pinus ponderosa* stands in Oregon and Washington. Particularly affected are even-aged pole stands 60 to 80 years old on poor sites. Excessive between-tree competition generally underlies the occurrence of beetle outbreaks, as infested trees typically have grown less than 1 inch in diameter during the decade prior to attack and have live crowns shorter than one-third of stem height. Severity of beetle-caused mortality is related to stand density, which indicates that thinning of dense stands will prevent beetle outbreaks.

Sartwell, C. and R. E. Dolph, Jr. 1976. Silviculture and direct control of mountain pine beetle in second-growth ponderosa pine. USDA For. Serv. Res. Note PNW-268, 8 pp.

ABSTRACT

In the first 5 years after treatment, silvicultural thinning reduced killing of *Pinus ponderosa* poletimber by *Dendroctonus ponderosae* by more than 90 percent and led to positive net stand growth in an eastern Oregon test. The felling and burning of infested trees also substantially reduced tree mortality caused by mountain pine beetle; even so, the treated stand declined in the post-treatment period due to damage by other agents. The practical effect of direct control in combination with thinning was no greater than that obtained by thinning alone.

Sartwell, C. and R. E. Stevens. 1975. Mountain pine beetle in ponderosa pine - prospects for silvicultural control in second growth stands. J. For. 73:136-40.

ABSTRACT

Mountain pine beetle is the major insect enemy of second-growth ponderosa pine in many interior areas of the western United States. Severe tree killing occurs predominately in dense stands where competition has substantially slowed growth of even the dominant trees. Experiments were begun in the 1960's to determine if beetle outbreaks can be prevented by silvicultural thinning.

Early results indicate that thinning of dense stands deserved major emphasis in efforts to minimize this pest problem.

Schenk, J. A., R. L. Mahoney, J. A. Moore, and D. L. Adams. 1980. A model for hazard rating lodgepole pine stands for mortality by mountain pine beetle. For. Ecol. and Mgmt. 3:57-68.

ABSTRACT

A stand hazard rating (SHR) was developed to rate lodgepole pine stands for tree mortality caused by the mountain pine beetle. The stand hazard rating is a function of Crown Competition Factor and percent lodgepole pine basal area, SHR = CCF * PLPP. This model can assist forest managers in assigning priorities for the application of silvicultural treatments to prevent or reduce the level of lodgepole pine mortality induced by mountain pine beetle.

* Schmid, J. M. 1968. Three insect predators of *Dendroctonus ponderosae* Hopkins. Ph.D. Diss., Univ. Mich., Ann Arbor, 180 pp.

Schmid, J. M. 1969. *Laphria gilva* (Diptera:Asilidae), a predator of *Dendroctonus ponderosae* in the Black Hills of South Dakota. Ann. Entomol. Soc. Am. 62:1237-41.

ABSTRACT

Adults of *Laphria gilva* (L.) killed about 1% of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), adults during the 1967 emergence period in the Black Hills. *L. gilva* adults commonly rest on tree trunks in *Dendroctonus*-infested areas, and capture *D. ponderosae* adults in flight. Males initiate mating from the resting position while females are hovering near the ground. Eggs are laid in the forest litter near tree bases. The predatory and ovipositional behavior are discussed in relation to predation on *D. ponderosae*.

Schmid, J. M. 1970. *Medetera aldrichii* (Diptera: Dolichopodidae) in the Black Hills. I. Emergence and behavior of adults. Can. Entomol. 102:705-13.

ABSTRACT

The number of *Medetera aldrichii* Wheeler adults emerging daily in 1966 and 1967 was low and irregular. Peak numbers apparently emerged 20-30 days prior to mass emergence of *Dendroctonus ponderosae* Hopkins although the numbers fluctuated through the mass emergence period of the beetle. Densities of emerging adults averaged less than 1 per square foot of bark and never exceeded 6.0 per square foot. Densities of the emerging flies and beetles did not appear related.

Adults mated on the bark surface of trees infested with *D. ponderosae;* mating habits are described.

Females oviposited in degenerate resin ducts in the bark surface. Two eggs per duct were the model number. Seven or more per duct were found in less than 5% of the ducts examined.

Schmid, J. M. 1970. *Enoclerus sphegeus* (Coleoptera: Cleridae), a predator of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) in the Black Hills, Can. Entomol. 102:969-77.

ABSTRACT

*Enoclerus sphegeus* Fabricius adults were most abundant on trees infested with *Dendroctonus ponderosae* Hopkins in May and June of 1966 and 1967. Greatest numbers of adults were observed on the bole from 0 to 5 ft. above ground, apparently in response to the activity of other scolytids. In the laboratory, each adult killed about 1 *D. ponderosae* per day, and each larva killed about 25 *D. ponderosae* during development. Mean larval densities were generally less than 0.2 per squre foot at four different sampling heights on the tree bole during the overwintering period. Densities were greatest at all heights in July. Maximum larval density was observed at the 1.5-ft height. Larvae began leaving the trees for pupation sites in July of both years. It is estimated that adult clerids consume less than 1% of the adult beetle population during their attack period and the clerid larvae kill 5-11% of the beetle brood.

Schmid, J. M. 1971. *Medetera aldrichii* (Diptera: Dolichopodidae) in the Black Hills. II. Biology and densities of the immature stages. Can. Entomol. 103:848-53.

ABSTRACT

*Medetera aldrichii* Wheeler larvae enter galleries of *Dendroctonus ponderosae* Hopkins through the beetle entrance holes. Observed larval densities of the fly were greatest in the May-June period following beetle attack. Densities were consistently greatest in the portion of the tree 5-10 ft. above ground; averaging around 3-4/sq. ft. The fly larvae probably cause a major share of the beetle mortality between August and the following May. The fly larvae pupate near beetle-created openings that lead from the galleries to the exterior.

Schmid, J. M. 1972. Emergence, attack densities, and seasonal trends of mountain pine beetle (*Dendroctonus ponderosae*) in the Black Hills USDA For. Serv. Res. Note. RM-211, 7 pp.

ABSTRACT

Beetles began emerging around July 1 and emerged in peak numbers on August 15, 1966 and 1967. Adults emerged almost simultaneously from the north and south sides of trees. More beetles emerged from the south side at 1.5 feet above ground than from the north side at the same height, but this relationship was reversed at heights of 5 feet and 10 feet. Densities of beetle attacks varied significantly with height and aspect.

Brood densities declined drastically between the time of attack and the following May. Relationships between beetle emergence evaluation techniques, and control operations are discussed.

Schmid, J. M. 1972. A problem in the Front Range: Pine beetles. Colo. Outdoors 21:37-9.

Schmid, J. M., S. A. Mata and W. F. McCambridge. 1985. Natural falling of beetle-killed ponderosa pine. USDA For. Serv. Res. Note RM-454, 3 pp.

ABSTRACT

Beetle-killed trees in the Front Range of Colorado were observed for their rate and direction of falling. No trees fell within the 2 years following infestation. Thereafter, trees generally fell at the rate of 3-5% per year unless winds exceeded 75 mph. Most trees fell to the east and broke off between ground level and 2 feet above ground.

Schmidt, W. C. 1982. Alternative solutions to mountain pine beetle: silviculture perspective. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 33-40.

* Schmitz, R. F. 1984. A passive aerial barrier trap suitable for sampling flying bark beetles. USDA For. Serv. Res. Note INT-348.

ABSTRACT

An inexpensive, 4-lb (1.8-kg), omnidirectional passive barrier trap of clear Plexiglas is used to census flying bark beetles, especially the mountain pine beetle, *Dendroctonus ponderosae*. The lightweight plastic components allow three traps to be suspended from a single vertical nylon line, using only tree limbs for support, at levels ranging to midcrown. The vertical line, with trap, is supported by a nylon line positioned in adjacent tree crowns with a bow and arrow or line gun. The design does not use sticky trapping surfaces, thereby eliminating the need to restick traps and reducing the time needed to recover and identify the catch. Insects caught

during one season by order were Coleoptera 49 percent (Scolytidae 18 percent), Hemiptera 14 percent, Diptera 14 percent, Hymenoptera 8 percent, Lepidoptera 8 percent, Homoptera 4 percent, Neuroptera 1 percent, and Orthoptera, Ephemeroptera, and Trichoptera <1 percent.

Schmitz, R. F. 1986. Effect of life cycle duration on factors limiting survival of the mountain pine beetle. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 25-36.

Schmitz, R. F., M. D. McGregor and G. D. Amman. 1980. Mountain pine beetle response to lodgepole pine stands of different characteristics. In A. A. Berryman and L. Safranyik (eds.). Dispersal of forest insects: evaluation, theory and management implications. Proc. of the 2nd IUFRO Conf., Wash. St. Univ., Coop. Ext. Serv. Pullman, WA, pp. 234-43.

ABSTRACT

Flying mountain pine beetles, *Dendroctonus ponderosae* Hopkins, were trapped using passive nondirectional barrier traps. Traps were hung at three levels above ground--1.8 m, midbole and midcrown--in thinned and unthinned lodgepole pine stands, *Pinus contorta* var. *latifolia* Engelmann. Overall, 48% of the 488 beetles trapped were caught in the midbole traps followed by the bottom (35%) and the midcrown traps (17%). Proportionately more females than males were usually caught at all levels, the highest proportion of females to males being in middle traps. Beetles were caught with about equal frequency in thinned and unthinned stands but more trees were infested in unthinned stands.

Schafer, G. A. and G. N. Lanier. 1970. A sexual character in pupae of *Dendroctonus* (Coleoptera:Scolytidae). Can. Entomol. 102:1487-8.

Schlotz, Kenneth C. 1972. Evaluation of a mountain pine beetle infestation. USDA For. Serv., Black Hills Nat. For. Rept. 14 pp.

Schönherr, V. J. 1971. Susceptibility of bark beetles (Coleoptera: Scolytidae) to blacklight. Z. Angew. Entomol. 68:244-50.

ABSTRACT

There is evidence that bark beetles distinguish different wave length of the light-spectrum. Two maxima can be discerned: one at 500-550 nm (green), the second below 400 nm (blacklight). In alternative experiments the blacklight proved much more attractive for bark beetles than any other wave length tested. In comparison with the human eye their visible range extends more to the short wave frequencies but seems to be restricted at the red part of spectrum.

* Schönherr, J. 1976. Mountain pine beetle: visual behavior related to integrated control. Proc. of the XVI IUFRO World Cong., Oslo, Norway, pp. 449-52.

Schultz, D. and B. Roettgering. 1984. A biological evaluation of lodgepole pine mortality in Parks Creek Drainage, Mt. Shasta Ranger District, Shasta-Trinity National Forests. USDA For. Serv., Pac. SW Reg. Rept. No. 84-26, 3 pp.

ABSTRACT

Mountain pine beetle caused extensive mortality of lodgepole and western white pines in the upper Parks Creek drainage during 1983. Factors which contributed to the outbreak include a high proportion of the stand consisting of overmature hosts of the mountain pine beetle, dense stocking, dwarf mistletoe and below normal snow packs in recent years. Mortality should be low at Parks Creek for the near future because most of the susceptible trees have already been killed. Other nearby drainages probably have stand conditions similar to those existing at Park Creek a few years ago. Stand treatments that increase vigor could probably prevent future mortality at Parks Creek and other similar drainages.

Sharp, R. H. and R. E. Stevens. 1962. New technique for spraying standing trees infested with bark beetles. J. For. 60:548-50.

Sharpnack, Nancy S. and John Wong. 1982. Sampling designs and allocations yielding minimum cost estimates for mountain pine beetle loss assessment surveys. USDA For. Serv., Methods Application Group, Rept. No. 83-8, 11 pp.

ABSTRACT

Tables of optimum sample size for each of three stages are presented for estimating mountain pine beetle loss in ponderosa and lodgepole pine forests in the western United States. These are listed for varying levels of precision and are based on data collected during surveys conducted between 1977 and 1980.

Shaw, D. 19__. Your forest-your decision. Colo. St. For. Serv., Colo. St. Univ., 20 pp.

* Shepherd, R. F. 1956. Population studies of the mountain pine beetle. Int. Rept. 1955-5. Can. Dept. Agr., For. Bio. Lab., Calgary, Alberta, 21 pp.

Shepherd, R. F. 1958. Population studies of the mountain pine beetle. Int. Rept. 1957-1. Can. Dept. Agr., For. Bio. Lab., Calgary, Alberta.

* Shepherd, R. F. 1959. Population studies of the mountain pine beetle. Int. Rept. 1958. Can. Dept. Agr., For. Bio. Lab., Calgary, Alberta.

* Shepherd, R. F. 1960. Distribution of the Black Hills beetle over the host tree and factors controlling the attraction and behavior of the adult. Ph.D. Thesis, Univ. Minn., Minneapolis, 82 pp.

Shepherd, R. F. 1962. Population studies of the mountain pine beetle. Int. Rept. Can. Dept. For., For. Entomol. and Pathol. Lab., Calgary, Alberta.

Shepherd, R. F. 1965. Distribution of attacks by *Dendroctonus ponderosae* Hopk. on *Pinus contorta* Dougl. var. *latifolia* Engelm. Can. Entomol. 97:207-15.

Shepherd, R. F. 1966. Factors influencing the orientation and rates of activity of *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). Can. Entomol. 98:507-18.

ABSTRACT

The tactic and kinetic responses of adult *Dendroctonus ponderosae* Hopkins were studied under varying conditions of light, temperature, humidity, gravity, and with different visual forms. Newly emerged adult *Dendroctonus ponderosae* Hopk. were attracted by high light intensity and utilized spot sources of light and surrounding objects, but not polarized light, for orientation. Flying adults were positively phototactic unless warmed above 35°C; egg-laying adults were negatively phototactic. High temperatures and light intensities increased the frequency of flights. The beetles were negatively geotropic but this could be masked by the attraction to light. Dark objects on a light background were attractive; the size of the object was important while the shape was not.

Temperature influenced orientation to some extent but its influence on rate of activity was far more pronounced; rate of walk followed a linear relationship with temperature. Humidity also affected orientation and rate of walk to some extent, although its effect was usually masked by other environmental factors.

* Shepherd, R. F. and J. A. Watson. 1959. Blue stain fungi associated with the mountain pine beetle. Can. Dept. Agr., For. Bio. Div. Bi-monthly Prog. Rept. 15:2-3.

Shrimpton, D. M. 1973. Extractives associated with wound response of lodgepole pine attacked by the mountain pine beetle and associated microorganisms. Can. J. Bot. 51:527-34.

ABSTRACT

Extractive changes that occur in the sapwood of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Englm.) in response to attack by the bark beetle (*Dendroctonus ponderosae* Hopk). and associated micro-organisms were studied. The most striking change was a large

increase in total terpene to levels well above that normally observed in sapwood or heartwood. Free acids, phenolics, and neutral components increased to a final concentration about the same as that in heartwood, but at a much slower rate than terpenes. Free sugar levels decreased. With the single exception of B-phellandrene no unusually high or unusually low levels of any one compound were observed in the wound response. All components found in the wound response were normal constituents of heartwood.

Shrimpton, D. M. 1978. Resistance of lodgepole pine to mountain pine beetle infestation. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 64-76.

ABSTRACT

This paper discusses the possible relationships between the mountain pine beetle *(Dendroctonus ponderosae* Hopkins) and the physiological processes of the lodgepole pine *(Pinus contorta* Douglas var. *latifolia* Engelmann) stem that act to heal wounds of the type caused by bark beetles. The resin canal system of lodgepole pine and production of secondary resins are described. The effects of moisture stress and the relationship of each resin system to maturation of the tree are also described. The interaction between tree response and the attacking beetle/blue stain-complex and the relationship between mountain pine beetle outbreak and physiological maturity of lodgepole pine are discussed.

Shrimpton, D. M. (ed.) 1982. Proceedings of the joint Canada/USA workshop on mountain pine beetle related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, 87 pp.

ABSTRACT

This two-day workshop on the economic and social problems related to the current mountain pine beetle epidemics in western Canada and the United States was jointly sponsored by the Canadian Forestry Service and the United States Forest Service, in cooperation with the Alberta and British Columbia Forest Services. The workshop was convened because the consequences of the extensive and widely spread epidemics are now regarded as being of crisis proportions in both countries.

In attendance from both countries were representatives from government, the forest industry, universities, National Parks, National and regional Forest Services, and the news media.

Reports at the workshop covered: the causative agents; the extent of the problem, economics and research needs; what is now being done and future plans; accomplishment barriers; and case studies. The differing points of view of private industry, forestry services, and National Parks from both countries were reported at the workshop. The workshop ended with a field trip through one of the oldest ongoing epidemics in British Columbia.

As a result of the workshop, a memorandum of understanding is being prepared between the two countries to further the cooperation at all levels in dealing with the problems related to mountain pine beetle.

* Shrimpton, D. M. 1983. Age- and size-related response of lodgepole pine to inoculation with *Europhium clavigerum*. Can. J. Bot. 51:1155-60.

Shrimpton, D. M. and R. W. Reid. 1973. Change in resistance of lodgepole pine to mountain pine beetle between 1965 and 1972. Can. J. For. Res. 3:430-2.

ABSTRACT

In 1965, 100 lodgepole pines (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in each of two areas near Radium, B.C. were graded for resistance to mountain pine beetle (*Dendroctonus ponderosae* Hopk.) by evaluating their response to inoculation with a fungus transported by the mountain pine beetle. In 1972, mortality of these trees due to mountain pine beetle or other causes was determined, trees were inoculated and the resistance of each was again evaluated. Most trees nonresistant in 1965 had been killed by the mountain pine beetle by 1972, whereas most trees rated resistant in 1965 were still alive and were again rated resistant.

Shrimpton, D. M. and A. J. Thomson. 1981. Use of physiological maturity to identify hazard of lodgepole pine stands from mountain pine beetle. In R. L. Hedden, S. J. Barras, and J. E. Coster (eds.). Hazard rating systems in forest insect pest management. USDA For. Serv. Gen. Tech. Rept. WO-27, pp. 149-53.

ABSTRACT

From research in our laboratory and a historical review of lodgepole pine (*Pinus contorta* Dougl.) stands sustaining mountain pine beetle (*Dendroctonus ponderosae* Hopk.) outbreaks throughout British Columbia, we proposed that to minimize losses from mountain pine beetle, stands should be managed for wood production and therefore harvested no later than the point when they reach physiological maturity. To test this proposal, we obtained growth data from a grove of lodgepole pine near which mountain pine beetle had been active from 1972 through 1979. Twelve dominant and codominant lodgepole pine were cut from the grove. Results of our examination show that the trees were near physiological maturity; therefore, this aspect of our hazard-rating system was confirmed.

Shrimpton, D. M. and J. A. Thomson. 1983. Growth characteristics of lodgepole pine associated with the start of mountain pine beetle outbreaks. Can. J. For. Res. 13:137-44.

ABSTRACT

The dynamics of tree and stand growth were studied in six small but expanding mountain pine beetle outbreaks in British Columbia. Stands had exceeded a previously reported hazard threshold of age 80 years by 26 years, and a second frequently used hazard threshold of 20.5 cm mean dbh was exceeded by 37 years. However, stands had exceeded maturity, as defined by the intersection of current annual increment (CAI) and mean annual increment (MAI), by an average of only 17 years. In all cases, the beginnings of the outbreaks were coincident with a period of reduced tree growth. This reduced tree growth was difficult to detect at breast height, with a consequent failure of the periodic growth ratio to indicate susceptibility. Although the stands were past the point of maturity, the dominant and codominant trees continued to add significant wood volume, which could make surveillance for incipient outbreaks and subsequent control actions cost effective.

Shrimpton, D. M. and A. J. Thomson. 1985. Relationship between phloem thickness and lodgepole pine growth characteristics. Can. J. For. Res. 15:1004-8.

ABSTRACT

Depth of the phloem (inner bark) layers in lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) is a factor in the development of outbreaks of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Five lodgepole pine stands in the interior of British Columbia spanning the ages affected by this beetle (47-147 years) were studied. Relationships were determined between thickness of the phloem layer and radial and area increments over various periods of time, as well as DBH. The thickness of the phloem layer declined over the age spanned in this study. The best predictor of phloem thickness was the basal area increment in the 6-10 years before sampling. Diameter was a poor predictor of phloem thickness.

* Silverstein, R. M. 1970. Attractant pheromones of Coleoptera. In M. Beroza (ed.), Chemicals controlling insect behavior. Academic Press, New York, pp. 21-40.

Skorheim, K. T. and D. E. Kistler. 1975. Helicopter removal of trees attacked by mountain pine beetle. Admin. Study, USDA For. Serv., Custer Ranger District, Black Hills NF.

Smith, R. H. 1963. Toxicity of pine resin vapors to three species of *Dendroctonus* bark beetles. J. Econ. Entomol. 56:827-31.

ABSTRACT

The vapor toxicity of saturated resin vapors of both host and non-host pines was determined for three species of *Dendroctonus: D. brevicomis* Le Conte, *D. monticolae* Hopkins, and *D. jeffreyi* Hopkins. Results with hard pines substantiate the hypothesis that bark beetles of this genus can tolerate saturated vapors of host resin but not of non-host resin, suggesting that resin is a determining factor in host specificity. Results with soft pines do not substantiate the hypothesis, suggesting that other properties of resin or non-resinous characteristics of these pines determine host specificity. A delayed effect in many tests with hard pine host resin suggests that even host resins can be deleterious under certain conditions.

Variable results were obtained with hybrid pines. Resin vapors of non-host x non-host hybrids were toxic. *D. brevicomis* and *D. jeffreyi* were usually significantly affected by non-host x host hybrid resin vapors while *D. monticolae* was not.

The overall results suggest that resin in some capacity may be an important factor in host resistance.

Smith, R. H. 1965. A physiological difference among beetles of *Dendroctonus ponderosae* (= *D. monticolae*) and *D. ponderosae* (= *D. jeffreyi*). Ann. Entomol. Soc. Am. 58:440-2.

ABSTRACT

A distinct difference was found between *D. ponderosae* Hopkins (= *monticolae* Hopkins) and *D. ponderosae* (= *jeffreyi* Hopkins) in their reaction to pine resin vapors and their individual components. Practically no difference was found between 2 different host sources of *D. ponderosae* (= *monticolae*). Therefore, the author recognizes a biological difference between *D. ponderosae* (= *monticolae*) and *D. ponderosae* (= *jeffreyi*) and recommends continuing to distinguish between them.

Smith, R. H. 1970. Length of effectiveness of lindane against attacks by *Dendroctonus brevicomis* and *D. ponderosae* in California. J. Econ. Entomol. 63:1180-1.

ABSTRACT

As a 2% diesel oil solution spray, lindane prevented attack by both the western pine beetle, *Dendroctonus brevicomis* LeConte, and the mountain pine beetle, *D. ponderosae* Hopkins, for 36 months; as a 2% aqueous emulsion it was effective for 22 months.

Smith, R. H. 1972. Xylem resin in the resistance of the Pinaceae to bark beetles. USDA For. Serv. Gen. Tech. Rept. PSW-1, 7 pp.

ABSTRACT

Xylem resin of Pinaceae is closely linked with their resistance and susceptibility to tree-killing bark beetles. This review of the literature on attacking adults suggests that all three resistance mechanisms proposed by Painter-prefernece, antibiosis, and tolerance-are active in this relationship: preference by attraction, repellency, and synergism; antibiosis by both chemical and physical properties; tolerance by healing and secondary resinosis.

Smith, R. H. 1976. Low concentration of lindane plus induced attraction traps mountain pine beetle. USDA For. Serv. Res. Note PSW-316, 5 pp.

ABSTRACT

Mountain pine beetles were induced to attack lodgepole pine sprayed with 0.2 percent or 0.3 percent lindane emulsion. Large numbers of beetles were killed and fell into traps at the base of the tree. The few successfully attacking beetles caused the sprayed trees to remain attractive to beetles for about two months. The incidence of attacked trees in the immediate area of the sprayed trees was apparently reduced.

Smith, R. H. 1981. Preserving the green sale value of dying ponderosa pine with lindane. USDA For. Serv. Res. Note PSW-350, 3 pp.

ABSTRACT

Pines with dead or dying crowns but without insects or stain in the lower trunk were sprayed in early spring with 1 percent lindane emulsion. The pheromone triplet of the western pine beetle was used to attract the beetle to some of the treated and untreated trees. By late fall 93 percent of the sprayed trees but only 7 percent of the unsprayed trees were still without insect attack or wood stain.

Smith, R. H., J. P. Cramer, and E. J. Carpenter. 1981. New record of introduced hosts for the mountain pine beetle in California. USDA For. Serv. Res. Note PSW-354, 3 pp.

ABSTRACT

In a pine arboretum near Placerville, in northern California, 27 pine species, varieties, or hybrids - many of them introduced species - were attacked by the mountain pine beetle *(Dendroctonus ponderosae* Hopk.). Among these 27 species, 7 were reported previously as either native or introduced hosts; 5 introduced species or hybrids hitherto unreported as hosts were killed; 5 introduced species or hybrids that were not killed were classified as probable hosts; and 10 species or hybrids were classified as only possible hosts. These results provide a basis for review and possible revision of the taxonomy of the mountain pine beetle.

Smith, R. H., G. C. Trostle and W. F. McCambridge. 1977. Protective spray tests on three species of bark beetles. J. Econ. Entomol. 70:119-25.

ABSTRACT

In an early extensive series of tests 2% oil solution or aqueous emulsion of lindane or chlorpyrifos, or 2% oil or water suspension of carbaryl prevented both attracted and forced attacks by *Dendroctonus brevicomis* LeConte, *D. ponderosae* Hopkins, and *D. adjunctus* Blandford on *Pinus ponderosa* Lawson and attacks by *D. ponderosae* on *P. contorta* Douglas. The period of effectiveness varied from 3 to more than 36 months depending on the formulation, insecticide, and type of attack: oil solution > emulsion; lindane > chlorpyrifos > carbaryl; forced attacks > attracted attacks. No marked differences could be found between beetle species in a given location. In a later series of attracted attack tests on ponderosa pine, however, 2% water emulsion of chlorpyrifos was not effective against *D. ponderosae*.

* Stallcup, P. L. 1963. A method for investigating avian predation on the adult Black Hills beetle. M.S. Thesis, Colo. St. Univ., Fort Collins.

Stark, R. W. 1978. The mountain pine beetle symposium aspirations. In A. A. Berryman, G. D. Amman, W. R. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 3-5.

ABSTRACT

The evolution of the symposium from a cooperative research project, an integrated pest management program involving the USDA Forest Service, the University of Idaho and Washington State University, is presented. The purpose of the symposium was to present a comprehensive state-of-the-art compendium on the current status of integrated management of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) for critical review by the users-forest managers. The aspiration of the contributors is to synthesize our current knowledge to provide a sound basis for implementation of management practices for regulation of destructive populations of the mountain pine beetle.

Stark, R. W., P. R. Miller, F. W. Cobb, Jr., D. L. Wood and J. R. Parmeter, Jr. 1968. Incidence of bark beetle infestation in injured trees. Hilgardia 39:121-6.

Steiner, G. 1932. Some nemic parasites and associates of the mountain pine beetle (*Dendroctonus monticolae*). J. Agr. Res. 45:437-44.

Stevens, R. E., D. B. Cahill, C. K. Lister, and G. E. Metcalf. 1974. Timing cacodylic acid treatments for control of mountain pine beetles in infested ponderosa pines. USDA For. Serv. Res. Note RM-262, 4 pp.

ABSTRACT

Careful timing is critical to success in post-attack use of cacodylic acid against mountain pine beetles. Acid must be introduced into infested trees before any larval galleries exceed 0.5 inch in length to achieve satisfactory beetle mortality. Since the beetle attack period may last more than 1 month, more than one visit per area will be necessary to locate and properly treat all the trees that become infested.

Stevens, R. E. and J. C. Mitchell. 1970. Lindane spray effective against mountain pine beetle in the Rocky Mountains. USDA For. Serv. Res. Note RM-167, 4 pp.

ABSTRACT

Lindane-diesel oil solution killed mountain pine beetle *(Dendroctonus ponderosae* Hopk.) in ponderosa pines *(Pinus ponderosa* Laws.) just as effectively as the commonly used insecticide, ethylene dibromide, but takes only 10 percent as much total spray.

Stevens, R. E., C. A. Myers, W. F. McCambridge, G. L. Downing and J. G. Laut. 1974. Mountain pine beetle in Front Range ponderosa pine: What it's doing and how to control it. USDA For. Serv. Gen. Tech. Rept. RM-7, 3 pp.

ABSTRACT

Mountain pine beetle is currently in outbreak status in Rocky Mountains ponderosa pine stands. Much of the cause is probably related to the presence of extensive areas of susceptible forest. What to do about it depends on the objectives of the landowners or land managers. Combined programs using all suitable control methods are proposed.

Stevens, R. E., W. F. McCambridge and C. B. Edminster. Risk rating guide for mountain pine beetle in Black Hills ponderosa pine. USDA For. Serv. Res. Note RM-385, 2 pp.

ABSTRACT

Average tree diameter, stand density, and stand structure are key elements used in the rating. Single-storied stands are most susceptible to heavy mountain pine beetle damage. Risk increases with d.b.h., reaching a maximum when trees are 12 inches d.b.h. and larger. During buildup of an outbreak, denser stands within a given mean diameter are more susceptible to invasion.

* Stewart, J. L. 1964. Black Hills beetle. Paper presented to the Black Hills Chapt. SAF, Jan. 31, 1964.

Stipe, L. 1975. Trends of a mountain pine beetle infestation in a high elevation stand in Yellowstone National Park. USDA For. Serv., Ogden, UT, 2 pp.

Stipe, L. E. 1976. Trends of a mountain pine beetle outbreak in a high elevation stand in Yellowstone National Park. USDA For. Serv., Ogden, UT, 4 pp.

Stock, M. W. and G. D. Amman. 1980. Genetic differentiation among mountain pine beetle populations from lodgepole pine and ponderosa pine in northeast Utah. Ann. Entomol. Soc. Am. 73:472-8.

ABSTRACT

Isozyme comparisons were made among mountain pine beetles (*Dendroctonus ponderosae* Hopkins) from 4 sites in NE Utah. Genetic differentiation was more closely associated with host tree species - lodgepole pine (*Pinus contorta* var. *latifolia* Engelmann) vs. ponderosa pine (*P. ponderosa* Lawson) - than with geographic distances among sites. Differences in average heterozygosity and frequencies at certain gene loci may be related to stages in the infestation cycle or environmental stress related to food quantity. Differences were small between males and females at any one site but among sites males showed greater differences than did females. A difference in gene frequencies between early-and late-emerging beetles was found at one site.

Stock, M. W. and G. D. Amman. 1983. Host effects on the genetic structure of mountain pine beetle, *Dendroctonus ponderosae*, populations. In L. Safranyik (ed.). The role of the host in the population dynamics of forest insects. Proc. IUFRO Conf., Banff, Alberta, Can., pp. 83-95.

ABSTRACT

To evaluate the effects of host tree species and phloem thickness on the genetic structure of mountain pine beetle populations, electrophoretic analyses were conducted on beetles from both lodgepole pine and ponderosa pine from a single stand in northeastern Utah. Stratification of the population by host tree species accounted for a significant portion of the differences among beetles. Beetles from ponderosa pine were more genetically diverse than those from lodgepole pine. Males were, in general, more genetically diverse than females. Male mountain pine beetles also varied more from tree to tree than did females. Beetles in thin-phloem lodgepole pine were more diverse than beetles in thick-phloem lodgepole pine. Males were more diverse than females in all thin-phloem lodgepole pine but not in thick-phloem lodgepole pine. We suggest direct relationship between levels of stress and genetic diversity in mountain pine beetles. Monitoring shifts in genetic diversity in a mountain pine beetle population from year to year might permit estimation of levels of stress being encountered by the population and could aid prediction of population levels in subsequent years.

Stock, M. W., G. D. Amman and P. K. Higby. 1984. Genetic variation among mountain pine beetle *(Dendroctonus ponderosae)* (Coleoptera: Scolytidae) populations from seven western states. Ann. Entomol. Soc. Am. 77:760-4.

ABSTRACT

Genetic characteristics of mountain pine beetles from 15 sites in seven western states were compared using electrophoresis. A high level of genetic similarity was observed among all groups, including those from areas previously considered separate ranges of *D. monticolae* (= *ponderosae)* and *D. ponderosae*.

Stock, M. W. and J. D. Guenther. 1979. Isozyme variation among mountain pine beetle *(Dendroctonus ponderosae)* populations in the Pacific Northwest. Env. Entomol. 8:889-93.

ABSTRACT

To examine genetic variation among mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae), populations in the Pacific Northwest, beetles from 6 localities were assayed for isozyme variation using starch gel electrophoresis. Greater genetic differences were observed among males in many samples than among the females. A cline in gene frequencies at the aspartate aminotransferase locus corresponded to north-south geographic distribution of beetle populations in Idaho. Similarity coefficients calculated between all possible pairs of populations indicated the presence of 2 major population units. The largest differences between populations appear to be attributable to long-term geographic isolation.

Stock, M. W., J. D. Guenther and G. B. Pitman. 1978. Implications of genetic differences between mountain pine beetle populations to integrated pest management. In A. A. Berryman, G. D. Amman, R. W. Stark and D. L. Kibbee (eds.). Theory and practice of mountain pine beetle management in lodgepole pine forests. Symp. Proc., For., Wild. and Range Exp. Sta., Univ. of Idaho, Moscow, pp. 197-201.

ABSTRACT

Electrophoresis was used to evaluate genetic diversity among mountain pine beetle *(Dendroctonus ponderosae* Hopkins) populations in relation to geographic location and host trees. Populations attacking lodgepole pine *(Pinus contorta* Douglas var. *latifolia* Engelmann) in pure and mixed stands, western white pine *(P. monticola* Douglas) mixed with lodgepole *latifolia,* and lodgepole var. *murrayana* (Greville and Balfour) mixed with ponderosa pine *(P. ponderosa* Lawson)

were examined. No genetic differences were detected among populations from stands of pure lodgepole var. *latifolia* or from *latifolia* mixed with ponderosa pine or white pine. In contrast, there was a larger degree of genetic difference observed between mountain pine beetles in lodgepole *murrayana* and all other populations. Further morphological, physiological and behavioral comparisons between mountain pine beetles in lodgepole *latifolia* and *murrayana* may reveal differences which contribute to variations in the insects' response to specific management practices, such as those employing pheromones.


* Struble, G. R. 1930. The biology of certain Coleoptera associated with bark beetles in western yellow pine. Univ. of Calif. Publ. Entomol. 5:105-33.

* Struble, G. R. 1933. Mortality of *D monticolae* Hopk. larvae due to low temperatures. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1934. The mountain pine beetle in sugar pine, season of 1933. Preliminary Report, USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1934. Nicotine injection of lodgepole pine in relation to mountain pine beetle attacks. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1935. The mountain pine beetle in sugar pine, season of 1934. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1935. Some recent studies of host selections by the mountain pine beetle in the California Region. USDA Bur. Entomol. and Plant Quar., Berkeley, CA, 9 pp.

* Struble, G. R. 1936. Studies on the nutritional requirements of mountain pine beetle larvae. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1936. Seasonal history and habits of *D. monticolae* in the Central Sierra Nevada Region. USDA Bur. Entomol. and Plant Quar., Berkeley, CA, 11 pp.

Struble, G. R. 1937. Number of *D. monticolae* ecodyces and period of each instar. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1937. Nutritional requirement of *Dendroctonus monticolae* Hopk., the development of rearing equipment and experimental technique, Progress Rept. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1937. "Deadline" as a protection against *Dendroctonus monticolae* attacks. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1938. *Temnochila virescens* and *Enoclerus sphegeus* in relation to the mountain pine beetle in sugar pine., USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1939. The green trogositid and red-bellied clerid in relation to the control of the mountain pine beetle in sugar pine. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1939. Artificial propagation of two native predators of the mountain pine beetle in sugar pine. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1939. Status of the mountain pine beetle in Mariposa Grove and recommendations for control. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1940. The habits and control of the mountain pine beetle in sugar pine. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1940. Native predators of the mountain pine beetle in sugar pine. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1941. Possibilities in improving the biological control of the mountain pine beetle by laboratory propagation of predators. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1942. Crown decadence of sugar pine in relation to attacks by the mountain pine beetle. Preliminary Report. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1942. Growth rate of sugar pine in relation to attacks by the mountain pine beetle. Preliminary report. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1942. Laboratory propagation of two predators of the mountain pine beetle. J. Econ. Entomol. 35:841-4.

Struble, G. R. 1942. Biology of two native coleopterous predators of the mountain pine beetle in sugar pine. Pan-Pacif. Entomol. 15:97-107.

* Struble, G. R. 1944. Preliminary results of the olfactory responses of the mountain pine beetle, season of 1943. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1945. Summary of investigative and control work on the mountain pine beetle in sugar pine stands of California. USDA Bur. Entomol., Berkeley, CA

* Struble, G. R. 1946. Possibilities of goop to control bark beetles under thick bark. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. 1956. Character of sugar pines attacked by the mountain pine beetle. Progress Report-Season of 1956. USDA For. Serv., 5 pp.

Struble, G. R. 1965. Attack pattern of mountain pine beetle in sugar pine stands. USDA For. Serv. Res. Note PSW-60, 7 pp.

ABSTRACT

Data accumulated for more than 25 years from old-growth sugar pine stands in central California showed that the mountain pine beetle preferred to attack mature and overmature trees with the most decadent crowns. Analyses included four age groups and eight crown types. Beetle outbreaks in second-growth sugar pine were nondiscriminating between trees. These outbreaks developed during drought when heavy populations were reared in snow-breakage debris.

* Struble, G. R. and L. H. Carpelan. 1939. External sex characteristics of two important native predators of the mountain pine beetle in sugar pine. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. and L. H. Carpelan. 1941. External sex characters of two important native predators of the mountain pine beetle in sugar pine. Pan. Pacif. Entomol. 17:153-6.

* Struble, G. R. and G. S. Hensill. 1935. Oil control experiments directed against *D. brevicomis, D. monticolae,* and flatheads, season of 1934. USDA Bur. Entomol., Berkeley, CA

Struble, G. R. and P. C. Johnson. 1955. The mountain pine beetle. USDA For. Pest. Leaflet 1, 4 pp.

Stuart, J. D., D. R. Geiszler, R. I. Gara and J. K. Agee. 1983. Mountain pine beetle scarring of lodgepole pine in south-central Oregon. For. Ecol. and Mgmt. 5:207-14.

ABSTRACT

Three forest disturbance periods, 1973-present, 1922-29, and 1827-46 were determined by aging scars on stems of lodgepole pine trees. All of the scars from the 1970's and 1920's, and most of the scars from the 1820's-40's were determined to be caused by the mountain pine beetle. A few scars from the earliest period may be the result of fire. Diagnostic characteristics of beetle scars are: resemblance to fire scars, pitch tubes, beetle emergence holes, blue stain, beetle galleries, retained bark on the scar face, and an orange or red discoloration around healthy sapwood. Beetle attacks tend to have a northeastern aspect and extend approximately two-thirds around tree boles at breast height.

By recognizing beetle scars it is possible to accurately age previous mountain pine beetle attacks. Many scars which had been thought to be of fire origin are actually caused by the mountain pine beetle.

Sturgeon, K. B. 1980. Evolutionary interactions between mountain pine beetle, *Dendroctonus ponderosae* Hopkins, and host trees in the Colorado Rocky Mountains. Ph.D. Dissertation, Univ. Colo., Boulder.

Sturgeon, K. B. and J. B. Mitton. 1986. Biochemical diversity of ponderosa pine and predation by bark beetles (Coleoptera: Scolytidae). J. Econ. Entomol. 79:1064-8.

ABSTRACT

To determine if mountain pine beetle, *Dendroctonus ponderosae* Hopkins, influences patterns of biochemical diversity in ponderosa pine, *Pinus ponderosa* Laws., monoterpene composition of xylem resin of trees that survived an infestation was compared with a random sample of living trees adjacent to the infestation. No significant differences were detected in means or variances between the two groups of trees. A comparison of these populations to populations of ponderosa pine with a history of western pine beetle, *D. brevicomis* LeConte, infestation revealed large differences in biochemical diversity between the two geographic areas. Association of geographic differences in biochemical diversity with insect species exhibiting different feeding habits suggests possible causal relationships between these two patterns.

Swain, K. M. 1968. Protecting ponderosa pine from bark beetle attack by use of a lindane-water emulsion spray. USDA For. Serv., Div. Timber Mgmt., San Francisco, CA, 13 pp.

* Swaine, J. M. 1912. Notes on some forest insects of 1912. 43rd Ann. Rept. Entomol. Soc. Ont., pp. 87-91.

* Swaine, J. M. 1914. Forest insect conditions in British Columbia, a preliminary survey. Can. Dept. Agr. Entomol. Bull. 7

* Swaine, J. M. 1918. Canadian bark beetles. II. A preliminary classification with an account of the habits, injuries and means of control. Can. Dept. Agr. Tech. Bull. 14

Swaine, J. M. 1925. The factors determining the distribution of Canadian bark-beetles. Can. Entomol. 57:261-6.

Swan, B. 1986. Pest management decision with regards to short and long term wood supply. In Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 151-6.

Tegethoff, A. C., T. E. Hinds and W. E. Eslyn. 1977. Beetle-killed lodgepole pines are suitable for powerpoles. For. Prod. Jour. 27:21-23.

ABSTRACT

Of 30.8 dead, standing, pole-size lodgepole pines per acre in southeastern Idaho, 38 percent yielded 35- to 40-foot long poles that met ANSI standards for size and form. Decay prevented the utilization of 12 percent of the trees for poles. Basal decay, responsible for rejecting over 50 percent of the trees, usually could be eliminated by long-butting trees from 4 to 8 feet. Trees dead for 3 years or longer attained an EMC of about 30 percent at 1 foot, and 14 percent at 16 feet, and higher, above the ground.

* Terrell, T. T. 1934. The flights or dissemination of forest insects, 1933. USDA Bur. Entomol., Coeur d'Alene, ID

Terrell, T. T. 1938. Nineth annual survey of the insect infestations of the Coeur d'Alene National Forest, 1937. USDA Bur. Entomol., Coeur d'Alene, ID

* Terrell, T. T. 1941. Annual insect surveys of the Coeur d'Alene National Forest, Idaho. 1930-41. USDA Bur. Entomol., Coeur d'Alene, ID

* Terrell, T. T. 1954. Mortality of the mountain pine beetle brood in the Lynch Lake control areas, Kootenai National Forest. USDA Bur. Entomol., Coeur d'Alene, ID

* Terrell, T. T. 1962. Mountain pine beetle infestation, Clearwater National Forest, 1961. USDA Bur. Entomol., Missoula, MT

Thomas, J. B. 1965. The immature stages of Scolytidae: the genus *Dendroctonus* Erichson. Can. Entomol. 97:374-400.

ABSTRACT

The external anatomy of the larvae and pupae of a number of species of the genus *Dendroctonus* was studied to determine its value in the classification of the genus. It was found that the larval and pupal characters supported the synonomy proposed in a revision of the genus based on imaginal characters recently published by another worker.

Thompson, G. 1975. Review of mountain pine beetle and other forest insects active in the Black Hills. USDA For. Serv., Rocky Mtn. Reg. Rept. R2-75-1, 35 pp.

Thomson, A. J., L. Safranyik, D. M. Shrimpton and H. S. Whitney. 1983. A theory of mountain pine beetle response to weather-induced changes in host resistance. Proc. IUFRO Conf., Banff, Alberta, Can., pp. 128-35.

ABSTRACT

Some relationships of mountain pine beetle population dynamics are discussed in relation to hypothetical modifications of the relationships resulting from weather-induced changes in host resistance. The modifications focus on the low attack densities characteristic of endemic populations. When host resistance is lowered, normally unsuccessful attack densities become successful and may result in relatively high larval populations. Host trees can normally resist attack except when the resistance mechanism is severely disrupted. Extreme reduction of resistance resulting in excessive drying of the phloem may be associated with poor survival of mountain pine beetle brood.

Thomson, A. J. and D. M. Shrimpton. 1984. Weather associated with the start of mountain pine beetle outbreaks. Can. J. For. Res. 14:255-8.

ABSTRACT

Extreme weather conditions associated with mountain pine beetle outbreaks were evaluated by graphical techniques for six locations throughout British Columbia. Three major associations of extreme weather patterns with lodgepole pine growth and mountain pine beetle outbreaks were identified. (i) Weather effects prior to, or early in, the growing season can reduce growth without releasing the beetle population. (ii) Weather conducive to beetle establishment and early brood development can occur too late in the season to have a noticeable effect on tree growth and therefore will not be recorded in the annual growth rings. (iii) Warm, dry periods during the summer are associated with tree growth reduction and the beginnings of outbreaks. In each of these three cases, extreme low precipitation levels were involved. Average precipitation in some months did not compensate for the effects of unfavourable extremes in other months on tree growth.

Thorne, G. 1935. Nemic parasites and associates of the mountain pine beetle *(Dendroctonus monticolae)* in Utah. J. Agr. Res. 51:131-44.

* Tilden, P. E. 1985. Remedial treatment of lodgepole pine infested with mountain pine beetle: efficacy of three insecticides. USDA For. Serv. Res. Note PSW-374.

ABSTRACT

Lindane is registered for remedial control of bark beetles; however, forestry uses are controversial and alternative chemicals are needed. Chlorpyrifos (Dursban 4E), carbaryl (Sevimol 4), and fenitrothion (Sumithion 8E) at 1, 2, and 4 pct active ingredient, and lindane at the registered dosage of 0.6 pct were sprayed on lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm). bolts infested with mountain pine beetles (*Dendroctonus ponderosae* Hopkins) in Colorado. Mean survival ratios (n = 10) of the proportions of beetles emerging from treated bolts to the proportion emerging from control bolts indicated that chlorpyrifos and fenitrothion at 2 and 4 pct were about as effective as lindane in reducing emergence.

Tkacz, B. M. and R. F. Schmitz. 1986. Association of an endemic mountain pine beetle population with lodgepole pine infected by Armillaria root disease in Utah. USDA For. Serv. Res. Note INT-353, 7 pp.

ABSTRACT

A random sample of 42 mature lodgepole pines revealed a significant and consistent association between infection by the root pathogen *Armillaria mellea* and the incidence of infestation by low population (endemic) levels of mountain pine beetle (*Dendroctonus ponderosae*). Of 21 trees with visual indicators of parasitic *A. mellea* infection, 19 were infested by the beetle, while only three of 21 trees with no visible indicators of *A. mellea* were infested. This is the first documentation of the association in lodgepole pine that may be an important factor affecting the dynamics of endemic level populations of the beetle.

* Trostle, G. C. 1959. Line plots versus strips for mountain pine beetle damage in lodgepole pine. USDA Berkeley, CA

Troxell, H. E., J. L. Tang, G. R. Sampson and H. E. Worth. 1980. Suitability of beetle-killed pine in Colorado's Front Range for wood and fiber products. USDA For. Serv. Res. Bull. RM-2, 10 pp.

ABSTRACT

Front Range beetle-killed ponderosa pine wood is suitable for most traditional uses of the species. Differences are: the beetle-killed timber is drier, usually blue-stained, and may contain wood borers and decay. Mechanical properties may be affected.

Tunnock, S. 1970. A chronic infestation of mountain pine beetle in lodgepole pine in Glacier National Park, Montana. J. Entomol. Soc. B.C. 67:23

ABSTRACT

An infestation of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) in lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) has been active since about 1950 in an area of 162 ha within Glacier National Park, Montana. Tree mortality is reported for 14 years. It fluctuated yearly, ranging from 0 to 4.7 trees per 0.405 ha (1 acre). Most trees above 25.4 cm in diameter had been killed by 1963.

Tunnock, S. and O. J. Dooling. 1976. Forest insect and disease conditions - 1975. USDA For. Serv., Northern Reg., Rept. No. 76-01, 14 pp.

Tunnock, S., M. D. McGregor. R. D. Oakes and H. E. Meyer. 1986. Mountain pine beetle infestations in the Northern Region during 1985. USDA For. Serv., Northern Reg., Rept. No. 86-9, 11 pp.

Turnbull, W. C. 1982. Parks Canada. Management policies and their relation to mountain pine beetle pest management programs. In D. M. Shrimpton (eds.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 58-59

Union Carbide Corporation. 1978. Mountain pine beetle control guide. For use in California, Colorado, Idaho, Oregon, Montana and Washington. Leaflet.

Union Carbide Corporation. 1978. Mountain pine beetle control guide. For use in Colorado, Wyoming, and South Dakota. Leaflet.

USDA. 1972. Forest management for the control and prevention of mountain pine beetle epidemics. Black Hills National Forest. USDA For. Serv., 12 pp.

USDA. 1974. Lane-Peet Study Area. Mountain pine beetle outbreak. Interdisciplinary team report. USDA For. Serv., 63 pp.

USDA. ____. Bark beetle infestation, Bridger National Forest - Bridger Division. USDA For. Serv., 8 pp.

USDA and CDA. 1983. Executive summary - Lodgepole pine/mountain pine beetle situation, United States and Canada, 1981. 16 pp.

USDA and CDA. 1984. Canada/U.S. Lodgepole pine mountain pine beetle program progress report number 2, December 31, 1984. USDA For. Serv. and CDA Can. For. Serv., 25 pp.

Usher, J. H. 1982. Management limitations and barriers of lodgepole pine. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on the mountain pine beetle and related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 60-64.

Van Sickle, G. A. 1982. The mountain pine beetle situation in Canada. In D. M. Shrimpton (ed.). Proceedings of the joint Canada/USA workshop on mountain pine beetle related problems in Western North America. Env. Can., Can. For. Serv. Rept. BC-X-230, pp. 13-15.

Van Sickle, G. A. 1986. The mountain pine beetle situation in British Columbia, 1984. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 9-13.

Van Sickle, G. A. 1986. Aerial surveys for pest damage assessment. In P. M. Hall and T. F. Maher (eds.). Mountain pine beetle symposium proceedings, Smithers, B. C., 1985. B. C. Ministry of Forests, Pest Management Rept. No. 7, pp. 51-4.

Vining, J., T. C. Daniel, H. W. Schroeder, and D. Morganster. 1982. Mountain pine beetle impacts on scenic values in forest residential sites.

ABSTRACT

Public-perception based methods for measuring forest scenic beauty may be used to determine the severity of pine beetle problems in forest home developments and to assess the effectiveness of management efforts to preserve scenic values. In a research project funded by the USDA Forest Service various features of forest home sites, including severity of insect damage, were measured at several residential developments in the Colorado Front Range. Perceived scenic beauty ws rated by public observers viewing photographs of the residential sites, and preliminary models for predicting scenic beauty judgements from measures of forest and development features were developed. Models of this kind may be useful for determining what pine beetle control eforts are most needed to preserve scenic values and for balancing the benefits and costs of insect control programs.

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Walsh, R. G., G. Keleta and J. P. Olienyk. 1981. Value of trees to residential property owners with mountain pine beetle and spruce budworm damage in the Colorado Front Range. Colo. St. Univ., Dept. of Econ., 116 pp.

ABSTRACT

The purpose of this study was to develop and apply a procedure for measuring the effect of mountain pine beetle and spruce budworm damage on the value of trees to owners of residential property in the Front Range of the Colorado Rocky Mountains. A representative sample of 64 mountain homeowners were interviewed during the summer of 1980. Homeowners reported maximum willingness to pay for trees contingent on changes in several important forest quality variables including: number of trees six inches dbh or more on improved and unimproved mountain property, on adjacent property in the near view, size of trees, expectation of insect infestation, visible insect damage, distribution of trees, change in species, and presence of large specimen trees as illustrated by color photos. The value of trees was estimated on the basis of the contingent value approach as recommended by the U. S. Water Resources Council guidelines for studies of the value of changes in environmental quality. Ordinary least squares regression techniques and tests of significance were applied in analysis of the data. The results of the study will contribute to an assessment of forest insect control programs, and to citizen participation in management decisions and cost sharing programs.

Walsh, R. G., G. Keleta, J. P. Olienyk and E. O. Waples. 1981. Appraised market value of trees on residential property with mountain pine beetle and spruce budworm damage in the Colorado Front Range. Colo. St. Univ., Dept. of Econ., 87 pp.

ABSTRACT

The purpose of this study was to develop and apply a procedure for measuring the effect of mountain pine beetle and spruce budworm damage to trees on the market value of improved and unimproved mountain property in the Front Range of the Colorado Rocky Mountains. A representative sample of 21 real estate appraisers of Front Range mountain property were interviewed during the summer and fall of 1980. Appraisers gave their professional opinions concerning the contribution of trees to the market value of mountain property contingent on changes in several important forest quality variables including: number of trees six inches dbh or more on the property, on adjacent property in the near view, size of trees, expectation of insect damage, visible insect damage, distribution of trees, change in species, and presence of large specimen trees as illustrated by color photos. Market value of trees was estimated on the basis of the contingent value approach as recommended by the U.S. Water Resources Council guidelines for studies of the value of changes in environmental quality. Ordinary least squares regression techniques and tests of significance were applied in analysis of the data. The results of the study will contribute to an assessment of forest insect control programs, and to citizen participation in management decisions and cost sharing programs.

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ABSTRACT

The premise that mature lodgepole pine forests are susceptible to mountain pine beetle attack when physiologically stressed was supported experimentally by manipulating the canopy density and availability of nitrogen in a 120-yr-old forest exposed to a high population of beetles. Where canopy density was reduced, either by us or by the insects, surviving trees significantly increased their resistance to attack over a 3-yr period. Increased resistance was reflected by changes in wood production per unit of leaf area (tree growth efficiency). Improved nitrogen nutrition hastened tree recovery but did not prevent attacks by beetles until growth efficiencies exceeded 100 g of wood production per square metre of foliage. Growth efficiency, as here defined, is an index of vigor that may reflect the relative ability of susceptible trees to produce defensive compounds following attack.

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Watson, J. A. 1970. Rhythmic emergence of the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera:Scolytidae). Can. Entomol. 102:1054-6.

ABSTRACT

Logs of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) supporting immature *Dendroctonus ponderosae* Hopkins were maintained under conditions of non-fluctuating temperature and light. The rate of emergence of the adult beetles exhibited a rhythmic, possibly ciradian, emergence pattern. When the temperatures fluctuated the emergence rate was always greatest in higher temperature.

Watson, J. A. 1971. Survival and fecundity of *Dendroctonus ponderosae* (Coleoptera:Scolytidae) after laboratory storage. Can. Entomol. 103:1381-5.

ABSTRACT

Adults of *Dendroctonus ponderosae* Hopkins were stored at 1°C in 2-mil polyethylene bags containing moistened excelsior. Under these conditions, 85% of the beetles survived after 30 days. Stored adults showed no decrease in fecundity but the percentage of females in their broods increased with storage duration. Handling prior to storage and interruptions in the storage period resulted in a decrease in survival. Female adults survived storage better than males.

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ABSTRACT

Infestation of the mountain pine beetle *(Dendroctonus ponderosae* Hopkins), the most important natural factor in management of lodgepole pine *(Pinus contorta* Douglas var. *latifolia* Engelmann) ecosystems, result in a number of management problems. These infestations seriously affect even flow and sustained yield and make the task of converting unmanaged to regulated forests very difficult. The result is chaos to orderly harvest. The beetles, rather than the manager, set priorities and schedule the cut. Infestations without the follow-up of fire or cutting, using an even-aged silviculture, hasten stands toward the climax stage in forest succession. Infestations may affect stand productivity. Too, access by big game, livestock and man may be affected. The effect on water quality and quantity is probably minimal. Infestations affect recreation and esthetics, build up high fire hazards, and may increase infections of dwarf mistletoe *Arceuthobium americanum* Nuttall ex Engelmann). Infestations create difficult utilization problems and cause special problems in areas closed to timber harvest. Because of the proclivity of the mountain pine beetle for large-diameter trees, management of lodgepole pine for timber production may face a disappointing future.


Whitehead, A. T. 1981. Ultrastructure of sensilla of the female mountain pine beetle, *Dendroctonus ponderosae* Hopkins (Coleoptera: Scolytidae). Int. J. Insect Morphol. & Embryol. 10:19-28.


ABSTRACT

The objective of this study is to provide a morphological foundation for electrophysiological studies on the sensilla of *D. ponderosae*. The sensilla on the antennae, labial and maxillary palps, galeae and fore-tarsi are described. The antennal club has several types of sensilla: (1) multiporous non-socketed pegs of varying lengths innervated by 2 neurons, (2) uniporous socketed pegs innervated by 5 neurons, (3) pegs innervated by only 1 neuron at the base, (4) tapered uniporous cones innervated by 4 neurons, and (5) fluted multiporous, non-socketed cones innervated by 4 neurons. All hairs on the fore-tarsi are innervated by 1 neuron at the base. The labial and maxillary palp-tips have: (1) digitform organs, (2) campaniform organs, (3) uniporous, socketed pegs innervated by 5 neurons, and (4) non-porpus pegs innervated by 3 neurons. Two small, uniporous, socketed pegs innervated by 4 neurons, are set into the maxillary palp-tip sidewall, and a single, sharp-tipped peg, innervated by 1 neuron, is found on the

tip. These 2 types are not seen on the labial palps. The ultrastructure of each type of sensillum found on both the maxillary and labial palps is similar; however, the number of uniporous and non-porous pegs on the labial palps is about half those of the maxilla. The maxillary galeae each have 3 types of sensilla: (1) numerous pegs of various sizes innervated by 1 neuron, (2) a single, possibly uniporous socketed peg innervated by 5 neurons, and (3) another single non-porous non-socketed peg innervated by 2 neurons.

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Whitney, H. S. 1971. Association of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) with blue stain fungi and yeasts during brood development in lodgepole pine. Can. Entomol. 103:1495-1503.

ABSTRACT

The physical association between *Dendroctonus ponderosae* Hopk. and its associated blue stain fungi *Ceratocystis montia* Rumb. and *Europhium clavigerum* Robinson and Davidson and the yeasts *Pichia pini* (Holst) Phaff, *Hansenula capsulata* Wickerham, and *H. holstii* Wickerham is described in single broods reared in bolts of lodgepole pine, *Pinus contorta* Dougl. var. *latifolia* Engelm. Eggs just prior to hatch and first-instar larvae were always in contact with the microorganisms whereas newly laid eggs, second-, third-, and fourth-instar larvae were not. During pupation, blue stain fungi and yeasts colonized pupal chamber walls. Transfer of these microorganisms to the new generation of insects was ensured when tenerals contacted the microorganisms lining the pupal chamber. Ensured physical contact between these organisms supports the hypothesis of a symbiosis between them.

Whitney, H. S. and S. H. Farris. 1970. Maxillary mycangium in the mountain pine beetle. Science 167:54-5.

ABSTRACT

A mycangium containing blue-stain fungi and yeasts is located in the cardo of the maxilla of the mountain pine beetle, *Dendroctonus ponderosae* Hopk. Symbiosis between one or more of the microorganisms and the insect is indicated.

Whitney, H. S. and O. J. Spanier. 1982. An improved method for rearing axenic mountain pine beetles, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). Can. Entomol. 114:1095-1100.

ABSTRACT

Improvements in the rearing methods for axenic mountain pine beetles were made by standardizing the nutritional and physical composition of a yeast-fortified ground phloem diet. By eliminating handling and possible malnutrition of neonate larvae, and by use of individual rearing units to reduce hazards associated with microbial contamination, one person produced batches of 400-500 axenic beetles. Beetles produced by this method were morphologically and anatomically equivalent to and more fecund than field beetles, were significantly smaller than their parental stocks, and perhaps required more degree hours above 40°C in developing from egg to adult.

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ABSTRACT

The strategy and tactics of direct control of the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) are reviewed and the absolute requirement for detection of incipient infestations and diligence in treatment application is reiterated. Modern approaches to the use of explosives, the entomopathogenic fungus *Beauveria bassiana* (Balsam) Vuillemin, improvements in standing single tree burning, a mechanical debarker and microwave power are described. The current and future needs for direct control are discussed.

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ABSTRACT

A mountain pine beetle outbreak, probably a result of stand stagnation, resulted in an apparent loss of over 35 years growth in a young ponderosa pine stand. The beetle-caused mortality is probably correlated linearly with the degree of over-stocking. The beetles may have reduced the value of the stand (projected to an age of 140 years) by as much as $265 per acre in some locations. Precommercial thinning would probably have greatly reduced these losses, as well as resulting in an increased growth rate.

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